

Wiley Finance Series

# Understanding Bitcoin

*Cryptography, Engineering and Economics*

PEDRO FRANCO

WILEY

---

# Contents

[Cover](#)

[Title page](#)

[Copyright](#)

[Dedication](#)

[About the Author](#)

[Acknowledgments](#)

[Foreword](#)

[Prologue](#)

[Preface](#)

[Part One: Introduction and Economics](#)

[Chapter 1: Foundations](#)

[1.1 Decentralized](#)

[1.2 Open Source](#)

[1.3 Public Asset Ledger](#)

[1.4 It's not Only the Currency, It's the Technology](#)

[Chapter 2: Technology \(Introduction\)](#)

[2.1 Centralized Database](#)

[2.2 Addresses, Transactions](#)

[2.3 Distributed Database, the Blockchain](#)

[2.4 Wallets](#)

[2.5 The Different Meanings of Bitcoin](#)

[Chapter 3: Economics](#)

[3.1 Medium of Exchange](#)

[3.2 Store of Value](#)

[3.3 Unit of Account](#)

[3.4 Deflation](#)

[3.5 Volatility](#)

[3.6 Effect on the Financial Industry and Monetary Policy](#)

[3.7 Regulation](#)

[Chapter 4: Business Applications](#)

[4.1 Money Transfer](#)

[4.2 Exchanges](#)

[4.3 Payment Processors](#)

[4.4 Web Wallets](#)

[4.5 Multisignature Escrow Services](#)

## [4.6 Mining](#)

## [4.7 ATMS](#)

---

### [Part Two: Bitcoin Technology](#)

#### [Chapter 5: Public Key Cryptography](#)

##### [5.1 Public Key Encryption](#)

##### [5.2 Digital Signatures](#)

##### [5.3 RSA](#)

##### [5.4 Elliptic Curve Cryptography](#)

##### [5.5 Other Cryptographic Primitives](#)

##### [5.6 Bitcoin Addresses](#)

#### [Chapter 6: Transactions](#)

##### [6.1 Transaction Scripts](#)

##### [6.2 Pay-to-Address and Pay-to-Public-Key Transactions](#)

##### [6.3 Multisignature \(m-of-n\) transactions](#)

##### [6.4 Other Transaction Types](#)

##### [6.5 Transaction Signature](#)

##### [6.6 Pay-to-Script-Hash \(P2SH\)](#)

##### [6.7 Standard Transactions](#)

#### [Chapter 7: The Blockchain](#)

##### [7.1 Hash Functions](#)

##### [7.2 Time-Stamp](#)

##### [7.3 Proof-of-Work](#)

##### [7.4 The Blockchain](#)

##### [7.5 Double-Spend and Other Attacks](#)

##### [7.6 Merkle Trees](#)

##### [7.7 Scalability](#)

#### [Chapter 8: Wallets](#)

##### [8.1 Symmetric-Key Cryptography](#)

##### [8.2 Offline Wallets](#)

##### [8.3 Web Wallets](#)

##### [8.4 Brain Wallets](#)

##### [8.6 Multisignature Wallets](#)

##### [8.7 Vanity Addresses](#)

##### [8.8 Simplified Payment Verification \(SPV\)](#)

##### [8.9 The “Payment Protocol” \(BIP 70\)](#)

#### [Chapter 9: Mining](#)

##### [9.1 Mining Technology](#)

[9.2 Pooled Mining](#)

[9.3 Transaction Fees](#)

[9.4 Selfish Mining](#)

## [Part Three: The Cryptocurrencies Landscape](#)

### [Chapter 10: The Origins Of Bitcoin](#)

[10.1 David Chaum's Ecash](#)

[10.2 Adam Back's Hashcash](#)

[10.3 Nick Szabo's Bit Gold and Wei Dai's B-Money](#)

[10.4 Sander and Ta-Shma's Auditable, Anonymous Electronic Cash](#)

[10.5 Hal Finney's RPOW](#)

[10.6 Satoshi Nakamoto](#)

### [Chapter 11: Alt\(ernative\) Coins](#)

[11.1 Litecoin](#)

[11.2 Peercoin](#)

[11.3 Namecoin](#)

[11.4 Auroracoin](#)

[11.5 Primecoin](#)

[11.6 Dogecoin](#)

[11.7 Freicoin](#)

[11.8 Other Alt-Coins](#)

[11.9 The Case For/Against Alt-Coins](#)

### [Chapter 12: Contracts \(the Internet of Money or Cryptocurrencies 2.0\)](#)

[12.1 Digital Assets](#)

[12.2 Smart Property](#)

[12.3 Micropayments](#)

[12.4 Autonomous Agents](#)

[12.5 Other Applications](#)

[12.6 Inserting Data into the Blockchain](#)

[12.7 Meta-Coins](#)

### [Chapter 13: The Privacy Battle](#)

[13.1 Network Analysis](#)

[13.2 Laundry Services](#)

[13.3 Greenlisting](#)

[13.4 Privacy-Enhancing Technologies](#)

[13.5 Fully Anonymous Decentralized Currencies](#)

### [Chapter 14: Odds and Ends](#)

[14.1 Other Transaction Protocols](#)

[14.2 Alternatives to Proof-of-Work](#)

[14.3 Merged Mining](#)

[14.4 Side-Chains](#)

[14.5 Open Transactions](#)

[14.6 Quantum Computing](#)

[14.7 Recent Advances in Cryptography](#)

[Bibliography](#)

[Index](#)

## List of Tables

[Table 3.1: Bitcoin wealth concentration. Data from Wile \(2013\)](#)

[Table 4.1: Daily transaction volume. Data from Grossman et al. \(2014\)](#)

[Table 6.1: Types of transaction. Data from webbtc.com on June 17, 2014](#)

[Table 9.1: Distribution of hash rate among mining pools. Data retrieved from blockchain.info/pools on June 17, 2014. Average of 4 days](#)

[Table 11.1: Market capitalization of some alt-coins. Data retrieved from coinmarketcap.com on April 19, 2014](#)

## List of Illustrations

[Figure 1.1: What Bitcoin is \(and isn't\)](#)

[Figure 2.1: Double-spending problem](#)

[Figure 2.2: Central counterparty holding a centralized database](#)

[Figure 2.3: Central counterparty single point of failure](#)

[Figure 2.4: Analogy between BitTorrent and Bitcoin](#)

[Figure 2.5: User sending funds. State of the database after the transaction has settled](#)

[Figure 2.6: Bitcoin as a distributed ledger](#)

[Figure 2.7: Bitcoin issuance theoretical schedule](#)

[Figure 3.1: Transaction per day \(with 14-day moving average\). Data from blockchain.info](#)

[Figure 3.2: Estimated daily transaction volume in bitcoins. Data from blockchain.info](#)

[Figure 3.3: Estimated daily transaction volume in USD. Data from blockchain.info](#)

[Figure 3.4: Miners revenue/transaction value, including 14-day moving average. Data from blockchain.info](#)

[Figure 3.5: BTC/USD. Data from blockchain.info](#)

[Figure 3.6: Annual Bitcoin velocity, using data from blockchain.info](#)

[Figure 3.7: Cumulative coin-days destroyed. Data from blockchain.info](#)

[Figure 3.9: Bitcoin annual percentage price volatility using a 6-month rolling window. Using bitcoin price data from blockchain.info](#)

---

[Figure 3.10: Money in circulation versus Bitcoin market cap, from Normand \(2014\), all figures converted to USD](#)

[Figure 3.11: Quantity Theory of Money and Bitcoin's possible impact](#)

[Figure 4.1: Money transmitters market capitalization versus Bitcoin. Data retrieved from Google Finance, Yahoo Finance and blockchain.info on May 10th, 2014](#)

[Figure 4.2: BTC/USD traded volume. Data from blockchain.info](#)

[Figure 4.3: Exchanges' market share for BTC/USD volume. Data from bitcoinaverage.com](#)

[Figure 4.4: Payment processor](#)

[Figure 4.5: Cashflows from mining ASIC](#)

[Figure 5.1: Public key encryption](#)

[Figure 5.2: Man-in-the-Middle attack](#)

[Figure 5.3: Digital signatures](#)

[Figure 5.4: RSA encryption scheme](#)

[Figure 5.5: RSA signature scheme](#)

[Figure 5.6: Example of a 2048-bit RSA key. All numbers in hexadecimal](#)

[Figure 5.7: Key size of several public key cryptography algorithms to obtain various security levels](#)

[Figure 5.9: Elliptic curve point doubling](#)

[Figure 5.10: Elliptic Curve identity element](#)

[Figure 5.11: Elliptic curve math](#)

[Figure 5.12: An example of a toy elliptic curve with 14 steps \(left\) and with the full cycle 270 steps \(right\)](#)

[Figure 5.13: Parameters in secp256k1 vs toy example. All numbers in hexadecimal](#)

[Figure 5.14: Elliptic curve digital signature algorithm](#)

[Figure 5.15: Address generation](#)

[Figure 6.1: Transaction](#)

[Figure 6.2: Unspent Transaction Outputs Cache \(UTXO\)](#)

[Figure 6.3: Scripting](#)

[Figure 6.4: Pay to Bitcoin address transaction](#)

[Figure 6.5: Stack for a pay-to-address script](#)

[Figure 6.6: Elements of a transaction](#)

[Figure 6.7: Pay-to-script-hash transaction](#)

[Figure 7.1: Hash functions](#)

[Figure 7.2: Merkle-Damgård construction](#)

[Figure 7.3: Time-stamping a group of transactions by publishing their hash in a newspaper](#)

[Figure 7.4: Linked time-stamping](#)

[Figure 7.5: Partial hash inversion proof-of-work](#)

[Figure 7.6: Hashcash](#)

[Figure 7.7: The blockchain](#)

[Figure 7.8: Dynamics of the blockchain](#)

[Figure 7.9: Security of a transaction inside the blockchain](#)

[Figure 7.10: Investment required to pull off a 51% attack with 1% and 50% probability of success](#)

[Figure 7.11: Merkle tree of the transactions in a block](#)

[Figure 7.12: Pruning of transactions in a block](#)

[Figure 7.13: Blockchain size \(MB\) on a logarithmic scale. Data from \[blockchain.info\]\(http://blockchain.info\)](#)

[Figure 8.1: Encryption of wallet private keys](#)

[Figure 8.2: Paper wallet generated using \[bitaddress.org\]\(http://bitaddress.org\)](#)

[Figure 8.3: Trezor<sup>™</sup> hardware wallet. Picture by SatoshiLabs \(\[www.bitcointrezor.com\]\(http://www.bitcointrezor.com\)\)](#)

[Figure 8.4: Type-1 deterministic wallet](#)

[Figure 8.5: Hierarchical Deterministic Wallet \(BIP 32\)](#)

[Figure 8.6: Tree created by an HD wallet](#)

[Figure 8.7: Vanitygen address generator](#)

[Figure 8.8: Vanitygen address generator with a shorter prefix](#)

[Figure 8.9: Vanitygen address generator with a string close to the size of an address](#)

[Figure 9.1: Bitcoins in circulation. Data from \[info">blockchain.info\]\(http://info.blockchain.info\)](#)

[Figure 9.2: Hash rate of the Bitcoin network. Hash rate data from \[blockchain.info\]\(http://blockchain.info\)](#)

[Figure 9.3: Mining revenue compared to electricity cost of different technologies. Price and hash rate data from \[blockchain.info\]\(http://blockchain.info\)](#)

[Figure 9.4: Probability of mining a block \(network-wise\)](#)

[Figure 9.5: Q-Q plot \(exponential distribution\) of the empirical time between blocks](#)

[Figure 9.6: Expected time to mine a block](#)

[Figure 9.7: Prioritization of transactions by miners](#)

[Figure 10.1: Satoshi Nakamoto](#)

[Figure 11.1: Network effect](#)

[Figure 12.1: Digital assets](#)

[Figure 12.2: Smart property](#)

[Figure 12.3: Market capitalization of some meta-coins. Data from coinmarketcap.com on April 1 2014](#)

[Figure 12.4: A Colored Coin genesis transaction](#)

[Figure 12.5: Ripple protocol](#)

[Figure 13.1: Transaction graph](#)

[Figure 13.2: The user graph corresponding to the transaction graph of Figure 13.1](#)

[Figure 13.3: Laundry service](#)

[Figure 13.4: Greenlisting](#)

[Figure 13.6: CoinSwap](#)

[Figure 13.7: Elliptic Curve Diffie–Hellman key exchange](#)

[Figure 13.8: Stealth addresses](#)

[Figure 13.9: A 3-colorable graph](#)

[Figure 14.1: Merged mining](#)



---

# Understanding Bitcoin

*Cryptography, engineering, and economics*

PEDRO FRANCO

WILEY

This edition first published 2015

©2015 Pedro Franco

---

*Registered office*

John Wiley & Sons Ltd, The Atrium, Southern Gate, Chichester, West Sussex, PO19 8SQ, United Kingdom

For details of our global editorial offices, for customer services and for information about how to apply for permission to reuse the copyright material in this book please see our website at [www.wiley.com](http://www.wiley.com).

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording or otherwise, except as permitted by the UK Copyright, Designs and Patents Act 1988, without the prior permission of the publisher.

Wiley publishes in a variety of print and electronic formats and by print-on-demand. Some material included with standard print versions of this book may not be included in e-books or in print-on-demand. If this book refers to media such as a CD or DVD that is not included in the version you purchased, you may download this material at <http://booksupport.wiley.com>. For more information about Wiley products, visit [www.wiley.com](http://www.wiley.com).

Designations used by companies to distinguish their products are often claimed as trademarks. All brand names and product names used in this book are trade names, service marks, trademarks or registered trademarks of their respective owners. Neither the publisher nor the author are associated with any product or vendor mentioned in this book. The material contained in this book is not related to any work the author has performed for any present or past employer. Opinions expressed in the book are solely those of the author and do not express the views of the author's current or past employers.

**Limit of Liability/Disclaimer of Warranty:** While the publisher and author have used their best efforts in preparing this book, they make no representations or warranties with respect to the accuracy or completeness of the contents of this book and specifically disclaim any implied warranties of merchantability or fitness for a particular purpose. It is sold on the understanding that neither the publisher nor the author are engaged in rendering professional services and neither the publisher nor the author shall be liable for damages arising herefrom. If professional advice or other expert assistance is required, the services of a competent professional should be sought.

A catalog record for this book is available from the Library of Congress.

A catalogue record for this book is available from the British Library.

ISBN 9781119019169 (hardback/paperback)

ISBN 9781119019145 (ebk)

ISBN 9781119019152 (ebk)

ISBN 9781119019138 (ebk)



---

## About the Author

Pedro Franco was born in Astorga, Leon (Spain). He holds a MSc in Electrical Engineering from ICA, a BSc in Economics, and an MBA from INSEAD. Pedro has been a consultant with McKinsey and Boston Consulting Group and a researcher with IIT prior to gaining more than 10 years of experience in financial markets holding Quant and Trading positions in Credit, Counterparty Risk, Inflation, and Interest Rates. He has created various mathematical libraries for financial derivatives, and managed teams of software developers.

The author can be contacted at [pfrancobtc@gmail.com](mailto:pfrancobtc@gmail.com).

---

# Acknowledgments

Thanks to Juan Ramirez for helping me gather the courage to write this book.

Thanks to Jon Beracoechea, Manuel Castro, and Robert Smith for exhaustively reviewing an early version of the book and providing many excellent suggestions. Thanks also to Eli Ben-Sasson, Alejandro and Alvaro Franco, Jeff Lim, Jan Pelzl, Stefan Thomas, Evan Schwartz, Rodrigo Serrano, Alena Vranova, and Bob Way for reviewing parts of the book and providing insightful comments.

Finally, thanks to my family for their patience and support; without them this book could not have been written.

---

# Foreword

I have been hoping for some time for a good book covering the technology and ideas behind Bitcoin to be written.

There is certainly a wealth of information about cryptocurrencies, but the field advances rapidly and is sometimes difficult for the non-initiated to understand the fundamentals and catch up with new developments. This book takes readers to a thorough understanding of the current state-of-the-art cryptocurrencies' technology, as well as its future economic and technological implications, without assuming any previous knowledge of the many fields that constitute Bitcoin. This is an enabling book that empowers the reader to participate in and contribute to this great adventure.

The book clearly exposes many concepts previously mainly known to insiders of the cryptocurrency world. It covers a wide range of topics, from the economics or the basic technology (such as elliptic curve cryptography, Merkle trees or the blockchain) to advanced cryptographic concepts (such as non-interactive zero-knowledge proofs), and explores many applications based on these ideas (such as multi-signature wallets or fully anonymous payment systems). All this is accomplished in a book that is very approachable and comprehensible.

Readers new to Bitcoin will surely be surprised by the ingenuity of the technology and the broad range of applications it enables. Those familiar with Bitcoin will find many sections, such as the sections on economics or advanced applications of cryptocurrencies, informative and thought provoking.

I believe Pedro's book will be well received in the business and financial community as well as by the general public, spreading the knowledge about Bitcoin and contributing to this technology crossing the chasm to the early majority.

Jeff Garzik  
Bitcoin Core Developer at BitPay, Inc.

---

# Prologue

- What is Bitcoin?
- It's a digital currency.
- Yeah, I get that, but who is behind Bitcoin?
- Nobody.
- What do you mean by nobody? Somebody must be controlling it!
- Nobody is controlling it, it is an algorithm.
- What? You mean like Terminator? So you say the world is going to be taken over by machines?
- Well, not the world, but maybe some businesses.
- Right... (rolling her eyes) But who controls the algorithm? Some mad scientist?
- It's an open source project.
- An open what?
- Yes, free code. You can download it from the internet and do with it whatever you want.
- So you don't have to pay for the "program"?
- Well, it's free as in freedom, not free as in beer.
- What does beer have to do with it?
- The code is not only free in the sense that you can use the program free of charge. It is also free in the sense that you can take the code, modify it, and release a program of your own with it.
- Wait a second! If I can do that then I can make my own bitcoins. What value does a bitcoin have then?
- No, you cannot mint your own bitcoins. What you can do is invent your own currency. And then you have to somehow make it gain acceptance...
- Oh, but this surely is the end of Bitcoin. If you can make as many currencies as you want, none of them would have any value.
- Currencies have value because of social convention. Bitcoin has value because people are willing to give value to it.
- I don't think you are right. Euros or dollars have value, everybody knows that.
- Well if bitcoins do not have value I will gladly accept your bitcoins (smiling).
- Bitcoins are not backed by anything so they cannot have value.
- Neither euros, dollars nor Bitcoin are backed by anything. You can say that all of them are the result of consensual hallucination. They have value because people give value to them. There is not much difference between them in this regard.
- I don't think so. You can buy things with euros or dollars, but what can you buy with bitcoins?

- You can buy almost anything with bitcoins. There are companies that will gladly accept your bitcoins in return for regular currency that you can use to buy anything. Converting bitcoins to sovereign currencies is just a technical interface and many companies provide this service. Besides, you can do things with bitcoins that you cannot do with sovereign currencies.
- Like what?
- For example, you could launch a crowd-funding campaign, just creating a special type of Bitcoin transaction.
- That sounds cool.
- There are many more applications that were impossible until now, such as a car which reads its ownership from the cloud. If you want to buy the car, you just pay the owner with bitcoins and the car knows automatically you are its new owner because it can look it up in Bitcoin's database. And there might be more applications to come that nobody has thought of yet, as was the case (and still is) with the internet.
- I guess I did not think of it that way.
- As they say, a currency is just the first application. The technology allows transferring value securely and in a decentralized way and this can lead to many new cool applications.
- I'm intrigued, I'd like to learn more.
- Great! I believe I have the right book for you...



---

# Preface

Opinions about Bitcoin are highly polarized between enthusiasts and skeptics. The author believes that the point of view of the skeptics is easier to grasp for someone not familiar with Bitcoin's technology. The objective of this book is to present the technology and arguments from both sides of the divide so that readers can form an informed opinion of their own.

What drives the passion of the enthusiasts is that Bitcoin is a technological breakthrough that creates many new and interesting applications. As is often the case with brand new technologies, many future applications of the technology might not be envisioned today. Who could have imagined the success of video streaming services or social networks in 1994? Enthusiasts feel the technology will yield many unforeseen applications for many years to come. The fact that most of these applications are intertwined with monetary economics makes it even more interesting.

The economic and technical aspects of Bitcoin are so intertwined that, in the opinion of this author, they should be tackled together. Arguing about one of them without understanding the other would be like trying to run a car with only one pedal: just pressing the gas or the brake pedal. Sure, the driver could descend a mountain with only the brake pedal, but then she could not go much further. Similarly, a driver with only the gas pedal could probably ascend a mountain, but she would be better off not trying to descend it. This book covers the technology behind Bitcoin, ranging from cryptography to software engineering to monetary economics.

References to Bitcoin's source code are scattered throughout the text, especially in the technical sections. These references are intended as clues for readers interested in the implementation of the Bitcoin protocol, but can be safely skipped by other readers.

This book is divided into three parts. The first part serves as an introduction to Bitcoin's technology and philosophy (Chapters 1 and 2). This part will also cover the economic arguments both in favor of and against Bitcoin (Chapter 3) and some business applications (Chapter 4). This part is designed for the time-constrained readers who are mostly interested in the business and economic impact of Bitcoin's technology.

The second part covers in detail how Bitcoin works, starting with public key cryptography (Chapter 5), transactions (Chapter 6) and the blockchain (Chapter 7). The last two chapters expand on related topics: wallets (Chapter 8) and mining (Chapter 9). In this line, two additional great resources for developers are the Developer Guide (Bitcoin Foundation, 2014a) and the Reference Guide (Bitcoin Foundation, 2014b) maintained by the Bitcoin Foundation, and the forthcoming book by Andreas Antonopoulos (Antonopoulos, 2014).

The third part completes the cryptocurrencies landscape. First, digital currency technologies preceding Bitcoin are discussed (Chapter 10). Then alternative cryptocurrencies based on Bitcoin (alt-coins) are covered (Chapter 11) and new applications of cryptocurrencies beyond payment systems are explored (Chapter 12). Most of the action in the cryptocurrencies community is focused on these new applications and Chapter 12 will introduce several of the brand new projects that are being built. Bitcoin is not anonymous, and Chapter 13 explores techniques that can be used to de-anonymize users as well as technologies that are being built to enable users to counter these techniques and enhance their privacy. The chapter concludes with an introduction to the technology, based on zero-knowledge proofs, to create fully anonymous decentralized digital currencies. The book concludes (Chapter 14)

with a discussion of some additional technical topics and the latest developments being discussed in the community.

---

An earlier version of this book has been registered in the blockchain. The hash of this earlier version is

1324585ce12bdf2c16995835e1ba1a04246592e7755c6c1933419fe80f97f10e  
and was registered in the blockchain in transaction

e144275426185d0a0b85e7bdcfdfbbaa6f7f750a522007aeaae6f0f8708838bb.

The blog for this book can be found at [understandingbitcoin.blogspot.com](http://understandingbitcoin.blogspot.com).

Madrid, July 2013

---

# **PART One**

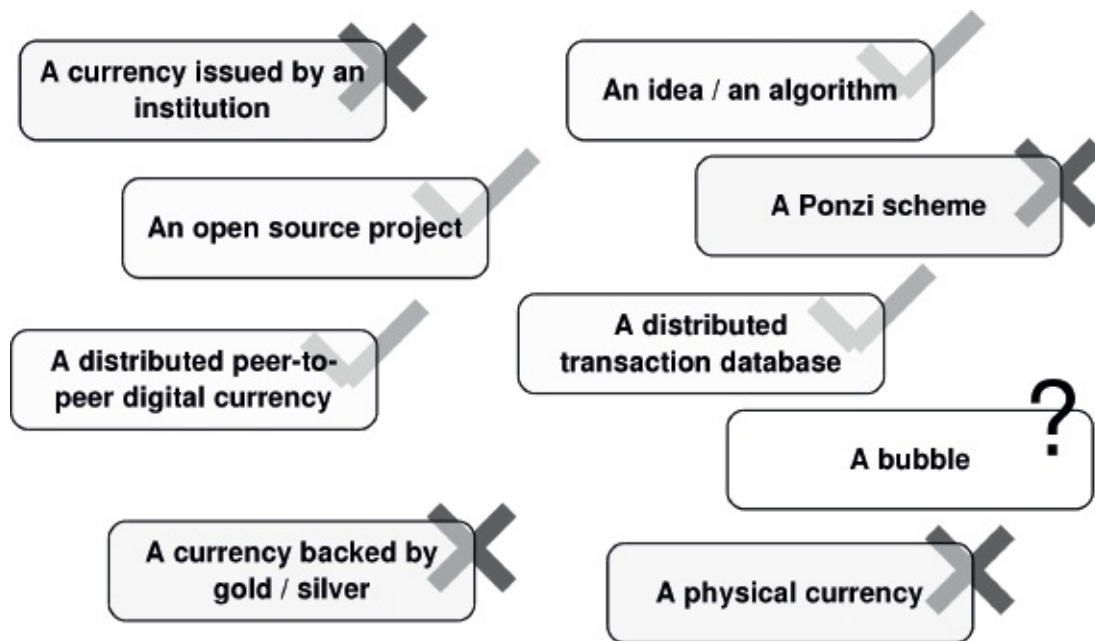
## **Introduction and Economics**

# CHAPTER 1

## Foundations

There has been ample media coverage of Bitcoin, and many public figures have been compelled to state their opinion. As Bitcoin is a complex topic, covering cryptography, software engineering and economics, it is difficult to grasp its essence and implications with only a superficial look at it. Thus some commentators might not have a clear picture of how it works and the implications. It is the goal of this book to equip the reader with the knowledge to evaluate the merits of this technology.

[Figure 1.1](#) summarizes some misconceptions around Bitcoin.



**FIGURE 1.1** What Bitcoin is (and isn't)

Bitcoin is a decentralized digital currency. This means there is no person or institution behind it, either backing it or controlling it. Neither is it backed by physical goods, such as precious metals. This might seem counter-intuitive at first glance: how could it exist if no one controls it? Who created it then? How did the creator lose control over it?

The answer to this seeming paradox is that Bitcoin is just a computer program. How exactly this computer program works is the subject of the second part of this book. The program has a creator (or creators) but his identity is unknown as he released the Bitcoin software using what is believed to be pseudonym: Satoshi Nakamoto. Bitcoin is not controlled in a tight sense by anyone. The creator did not lose control of it because he (she?, they?) never owned the code. The code is **open source** and thus it belongs to the public domain, as will be further explained in section 1.2.

One of the most innovative features of Bitcoin is that it is **decentralized**. There is no central server where Bitcoin is running. Bitcoin operates through a peer-to-peer network of connected computers. Bitcoin is the first digital currency built in a decentralized way, a technological breakthrough. The decentralized nature of Bitcoin will be further explored in section 1.1.

Bitcoin creates its own currency called bitcoin, with a small b. The creation of a currency is integral to how the system operates, as it serves two simultaneous purposes. First, it serves to represent value. Second, issuance of new bitcoins is used to reward operators in the network for securing the

distributed ledger. These two functions cannot be unbundled without significantly changing the design.

---

The heart of the Bitcoin network is a database holding the transactions that have occurred in the past as well as the current holders of the funds. This database is sometimes called a ledger, because it holds the entries representing the owners of the funds. Bitcoin is not the first distributed database to be created. However, the requirements of a financial database are different from those of other applications, such as file sharing or messaging systems. In particular, financial databases must be resilient against users trying to double-spend their funds, which Bitcoin solves elegantly. This is explored in the following sections and in Chapter 2.

Some critics have argued that Bitcoin is a **Ponzi scheme**. **It is not**. In a Ponzi scheme there is a central operator who pays returns to current investors from new capital inflows. First of all, in Bitcoin there is no central operator who can profit from the relocation of funds. Second, there is no mechanism to deflect funds from new investments to pay returns. The only funds recognized in the Bitcoin protocol are bitcoins, the currency. Transfers of bitcoins are initiated by the users at their will: the protocol cannot deflect funds from one user to another. Third, a new investment in Bitcoin is always matched with a disinvestment. Investors who put money into bitcoins usually operate through an exchange where they buy the bitcoins from another investor who is selling her investment. There is simply no new investment flowing into bitcoins: the amount of sovereign currency that has flown into bitcoins exactly matches the amount that has flown out of bitcoins.

However, bitcoin, the currency, can be a bubble. Whether the value of bitcoin crashes, holds, or increases depends on whether bitcoins will be used in the future for different applications. There are several interesting applications for Bitcoin, of which the most straightforward (but not the only) are to serve as a medium of exchange and a store of value. It is too early to tell whether any of these applications will become important in the future. The merits of bitcoins as medium of exchange and store of value are explored in Chapter 3.

Finally, Bitcoin is not just a currency but a whole infrastructure that can be used to transfer value digitally: see section 1.4 and Chapter 12.

## 1.1 DECENTRALIZED

Most currencies in use today are fiat currencies, where the currency is issued by the government and its supply managed by a central bank.

## FIAT MONEY

Most currencies today (Euro, US Dollar) are fiat money. Fiat money does not have intrinsic value, as it is not backed by anything. It is called fiat money because there is a government decree (“fiat”) declaring the currency to be legal tender. The acceptance of fiat money depends on expectations and social convention. If confidence in a currency is lost, usually because of irresponsible monetary policy, fiat money can stop being accepted.

Experience has shown that leaving monetary policy in the hands of governments is usually not a good idea, as governments could have an incentive to increase the monetary supply to solve pressing short-term financial problems. This behavior can lead to high inflation and a loss of confidence in the currency.

The conventional solution is to entrust monetary policy to a semi-independent central bank. The central bank is tasked with managing the monetary policy, usually with the goals of economic growth, price stability, and, in some cases, stability of the financial system.

Bitcoin is based on a peer-to-peer network of computers running the software. These computers are called nodes. Participants in the network might be running nodes for different reasons: for profit as in the case of miners (Chapter 9), to manage full-node wallets (Chapter 8), to collect and study information about the network (Chapter 13), or simply as a social good.

Bitcoin’s decentralized nature contrasts to the structure of fiat currencies. Central banks make monetary decisions after evaluating evidence gathered from the evolution of the economy. In a decentralized system such as Bitcoin, discretionary decisions are not possible. The original creators of the system have to take most of the decisions upfront at the design phase. These decisions have to be carefully balanced, and take into account the incentives of the different users, otherwise the decentralized system is doomed to fail. In Bitcoin the monetary policy follows a simple rule: the final monetary base is fixed at around 21 million bitcoins and new bitcoins are minted at a planned schedule and paid to users who help secure the network. This serves the double purpose of providing the bitcoins with value due to their scarcity and creating incentives for users to connect to the network and help secure it by providing their computational power.

Control in a centralized system is usually concentrated in an institution or a small group of key people. Thus changes in a centralized system are relatively straightforward to decide and implement. Control in a peer-to-peer network is more subtle: changes in a peer-to-peer network have to be agreed by a majority of the peers at least. But even then, if a strong minority does not agree to a change, implementing the change can be technically challenging as the network runs the risk of a split.

One advantage of the decentralization of power is that changes that are contrary to the interests of most users would be rejected. In contrast, in centralized systems sometimes the outcomes are adverse to most of the participants, as in a currency debasement by excessive printing which usually leads to high inflation.

Another feature of decentralized systems is their resilience. Decentralized systems are robust against attacks either by insiders or by external forces. This feature might have been critical for the existence of Bitcoin. Earlier centralized attempts to create digital currencies (section 2.1) were forced down by governments. However, to force down a decentralized system, all individual users must be forced

down, which is a much harder task. Bitcoin's peer-to-peer nature makes it censorship-resistant, claim its supporters.

---

The technology to securely (cryptographically) transfer value digitally had been available many years before the creation of Bitcoin (Chapter 10). However, it had always required the creation of a centralized trusted party. Bitcoin not only does not require a central trusted party to operate, but it is also designed to resist the attacks of malicious participants in the peer-to-peer network. As long as these malicious participants do not control a majority of the network these attacks will not succeed (section 7.5).

The main technological breakthrough accomplished by Bitcoin is solving the double-spending problem in a distributed financial database. A double-spend attempt occurs when a user tries to spend some funds twice. All financial systems must reject these attempts. This is relatively straightforward in a centralized system, as transactions are recorded in a central database and future spending attempts are checked against this database first. In a decentralized system, many copies of the database are shared among the peers, and keeping a consistent state of the database is a difficult computational problem<sup>1</sup>. In the context of Bitcoin the problem is how the network can agree on the state of the distributed database when messages between the nodes can be corrupted and there might be attackers trying to subvert the distributed database. Bitcoin gracefully solves this problem (section 2.3 and Chapter 7).

## 1.2 OPEN SOURCE

Bitcoin is open source software. **Open source** software makes the source code available for anyone to use, modify, and redistribute free of charge. Some well-known open source software products include the Linux and Android operating systems or the Firefox web browser. A large portion of the internet infrastructure runs on less known (but no less important) open source software. The goal of open source is to make software development similar to academic peer-reviewed research. By publishing the source code for anyone to see and check, open source aims to increase the quality of the software.

The difference between open source software and proprietary software lies in their licenses. A proprietary software license grants the right to use a copy of the program to the end user. However, ownership of the software remains with the software publisher. In contrast, an open source license grants the user the right to use, copy, modify, and redistribute the software. The copyright of the software remains with the creator, but the creator of an open source software transfers the rights to the user as long as the obligations of the license are met.

Another difference between proprietary and open source programs is that proprietary programs are usually distributed as compiled binaries. This means that the software is usually distributed in machine language. Users willing to gain knowledge on what the software is doing must interpret the machine code in a time-consuming process called reverse engineering (Eilam, 2005). Most proprietary licenses forbid the use of these reverse engineering techniques. Thus under a proprietary license the user is usually not allowed to understand or seek knowledge of what the software is actually doing. In contrast, open source software is always distributed with a copy of the source code. A user who wants to understand what the software is doing can just read the source code. Cryptographic open source software has the advantage that it allows users to check that the code does not contain any backdoor or security vulnerabilities<sup>2</sup>.

It is unlikely that Bitcoin could have been released under a proprietary license. Had Bitcoin been

released as closed-source, its creator could have easily inserted code that deviated from the specification: say, creating new bitcoins and sending them to an address controlled by him. Most users presumably would not have accepted decentralized cryptographic financial software distributed as a compiled binary and with a proprietary license. It is telling that most competing cryptocurrencies (Chapter 11, section 12.7), have either been launched using an open source license or have switched to an open source license.

Open source licenses grant the user the right to use, copy, modify, and redistribute the software. Different licenses may impose different obligations on the users. Broadly speaking, open source licenses belong to one of two families:

- **“Copyleft.”** These licenses impose the obligation to distribute derived works under the same license. If a user of the software makes modifications to it, she is obliged to release the modified software under the same license. This is referred to as the share-alike requirement. Thus “copyleft” licenses preserve the open source nature of the software as it is modified. An example of a “copyleft” license is the GNU **Public License (GPL)**.
- **“Permissive.”** These licenses impose very few restrictions on the redistribution of the software, usually just that the derived software acknowledges the original software and retains the copyright notice. Proprietary software that incorporates software released under an open source permissive license retains its proprietary nature as the license usually only requires that the proprietary software includes the copyright notice. Several common open source licenses belong to this family, such as the BSD license, the MIT License or the Apache License. Bitcoin was released under the MIT license.

Proprietary software requires that the company issuing the software maintains and updates it. In contrast, open source software acquires a life of its own once released. It usually does not matter if an original creator decides to stop working on an open source project, as other developers could take it over. For this reason it does not matter who Satoshi Nakamoto is, or that he has moved on. Open source projects are resilient: even if some developers are forbidden or discouraged to work on a project, other developers from all around the world can take over.

Under an open source license it is legitimate to start a new independent software project from a copy of an original project. This process is called **forking**. The threat of a fork can often keep the developers of an open source project honest. If the developers of a project introduce changes that are detrimental to the users of the software, anybody can create a fork, undo those changes and continue the development. Users will most likely follow the fork without the undesired features. Thus forking can be seen as a kill switch that prevents developers from evolving a project against their users. Most large open source projects are rarely forked<sup>3</sup>. Bitcoin is somewhat special in this respect, as it has been forked many times by developers wishing to test new concepts. This has given rise to many alternative cryptocurrencies called alt-coins. Alt-coins will be covered in more detail in Chapter 11.

Open source advocates argue that companies releasing proprietary software often lose the incentive to innovate once a product has achieved a dominant market position. Many software markets behave like natural monopolies where a product with first mover advantage can capture a large market share. Thus innovation in many software categories is low, these advocates suggest. In contrast, if an open source software captures the majority of the market this does not bring about the end of innovation, as anybody can keep on adding improvements to the software. Thus the pace of innovation in open source software can be higher than in closed source software.

One problem facing many open source projects is the **tragedy of the commons**. Although many



- [Handbook To Life In The Medieval World, Volumes 1-3 online](#)
- [Fate Interrupted \(Fate Interrupted, Book 1\) online](#)
- [download On the Back Roads: Discovering Small Towns of America pdf, azw \(kindle\)](#)
- [read Kant and the Problem of Metaphysics \(5th Edition\) \(Studies in Continental Thought\) online](#)
- **[download online The Development of Ethics, Volume 1: From Socrates to the Reformation](#)**
  
- <http://sidenoter.com/?ebooks/Handbook-To-Life-In-The-Medieval-World--Volumes-1-3.pdf>
- <http://sidenoter.com/?ebooks/Hybrid-Reality--Thriving-in-the-Emerging-Human-Technology-Civilization--TED-series-.pdf>
- <http://creativebeard.ru/freebooks/On-the-Back-Roads--Discovering-Small-Towns-of-America.pdf>
- <http://test1.batsinbelfries.com/ebooks/Professional-Portrait-Retouching-Techniques-for-Photographers-Using-Photoshop--Voices-That-Matter-.pdf>
- <http://twilightblogs.com/library/All-The-Songs--The-Story-Behind-Every-Beatles-Release.pdf>