

VOLUME I

Blockchain for Financial Markets

*A Practitioner's Guide to Settlement,
Tokenization, and Distributed Ledgers*

Abdelkader Bousabaa

University of Paris-Saclay

First Edition — 2025

SEVEN LIONS EDITIONS

Blockchain for Financial Markets: A Practitioner's Guide to Settlement, Tokenization, and Distributed Ledgers

Copyright © 2025 Seven Lions Editions.

All rights reserved. No part of this publication may be reproduced, distributed, or transmitted in any form or by any means, without the prior written permission of the author, except in the case of brief quotations embodied in critical reviews and certain other non-commercial uses permitted by copyright law.

First Edition

ISBN : 979-8-19-535837-2

The companion website (financial-blockchain-project.com) provides interactive diagrams, full source code, lecture slides, and curated links freely available to all readers and students.

The opinions expressed in this work are those of the author and do not necessarily represent the views of any institution or regulatory body.

*To the back-office teams whose invisible work
keeps financial markets running every day.*

*And to those who will build
the infrastructure of tomorrow's markets —
may it be simpler, safer, and faster.*

Contents

Preface	xv
I The Settlement Problem	1
1 How Does a Trade Actually Settle?	3
1.1 From Execution to Settlement: The Full Chain	3
1.1.1 Execution	4
1.1.2 Clearing	4
1.1.3 Settlement	4
1.2 The Key Players	6
1.2.1 Brokers and Prime Brokers	6
1.2.2 Central Counterparties (CCPs)	6
1.2.3 Central Securities Depositories (CSDs)	7
1.2.4 Custodians	8
1.3 The Settlement Cycle: T+2 and Beyond	9
1.3.1 Why T+2?	9
1.3.2 The Road to T+1	10
1.4 What Actually Happens During Settlement	11
1.4.1 Matching and Confirmation	11
1.4.2 Netting	12
1.4.3 Delivery versus Payment	12
1.5 The Numbers: Scale and Cost	13
1.6 Summary	14
2 What Can Go Wrong — and Does	17
2.1 Settlement Fails	17
2.1.1 What Is a Fail?	17

2.1.2	The Scale of the Problem	18
2.1.3	CSDR Settlement Discipline	20
2.2	Counterparty Risk	20
2.2.1	Pre-Settlement Risk	21
2.2.2	Principal Risk	21
2.3	Reconciliation: The Hidden Cost	22
2.3.1	What Reconciliation Is	22
2.3.2	The Cost of Discrepancies	23
2.4	Systemic Risk	23
2.4.1	Interconnectedness	23
2.4.2	Operational Concentration	24
2.5	The Fragmentation Problem	24
2.6	Summary	25
3	The Ideal Settlement System	27
3.1	The Design Criteria	27
3.2	Delivery versus Payment: The Atomic Ideal	28
3.2.1	What Is Atomic Settlement?	28
3.2.2	Why Atomicity Matters	29
3.3	Finality and Irrevocability	30
3.4	T+0: Instant Settlement	30
3.4.1	The Vision	30
3.4.2	The Challenges	31
3.5	No Reconciliation: The Single Source of Truth	32
3.6	Resilience: No Single Point of Failure	33
3.7	Privacy: Seeing What You Need to See	33
3.8	Compliance and Interoperability	34
3.9	The Role of Trust in Settlement	34
3.10	From Vision to Technology	35
II	Blockchain Fundamentals	37
4	What Is a Distributed Ledger?	39
4.1	The Problem with Central Books	39
4.1.1	A Tale of Two Banks	39
4.1.2	Single Points of Failure	40

4.1.3	The Reconciliation Problem	40
4.2	Distributed Systems	40
4.2.1	Centralized versus Distributed	40
4.2.2	Peer-to-Peer Networks	41
4.3	The Ledger as a Data Structure	41
4.3.1	What Is a Ledger?	41
4.3.2	Ordering and Immutability	43
4.4	From Single Ledger to Blockchain	43
4.5	Ownership in a Distributed World	44
4.5.1	The Three Elements of Ownership	44
4.5.2	Authorization: Signing Transactions	44
4.6	The Double-Spending Problem in Finance	45
4.6.1	The Classic Problem	45
4.6.2	Its Equivalent in Settlement	45
4.7	DLT versus Blockchain: A Clarification	46
4.8	Summary	46
5	How Integrity Is Achieved	49
5.1	The Challenge of Integrity Without Authority	49
5.2	Cryptographic Hash Functions	50
5.2.1	What Is a Hash?	50
5.2.2	A Hash as a Digital Fingerprint	51
5.3	Linking Blocks: The Chain	51
5.3.1	From a List to a Chain	51
5.3.2	Detecting Tampering: A Worked Example	52
5.4	Asymmetric Cryptography	53
5.4.1	The Lock Box Analogy	53
5.4.2	Public and Private Keys in Settlement	53
5.5	Digital Signatures	54
5.5.1	The Post-Office Seal Analogy	54
5.5.2	Signing a Settlement Instruction	54
5.5.3	Verifying the Signature	55
5.6	The Three Properties Together	56
5.7	Summary	57

6	Consensus: Who Decides What Is True?	59
6.1	The Byzantine Generals Problem	59
6.1.1	The Classic Formulation	59
6.1.2	Application to Financial Networks	60
6.2	Proof of Work	60
6.2.1	The Mechanism	60
6.2.2	Why It Is Unsuitable for Financial Markets	61
6.3	Proof of Stake	62
6.3.1	The Mechanism	62
6.3.2	Advantages and Limitations for Settlement	62
6.4	Practical Byzantine Fault Tolerance (PBFT)	63
6.4.1	The Mechanism	63
6.4.2	Why It Is Preferred in Permissioned Networks	63
6.5	Choosing a Consensus Mechanism for Settlement	64
6.5.1	The Key Criteria	64
6.5.2	A Decision Framework	65
6.6	Summary	65
7	Smart Contracts: Automating Settlement	69
7.1	What Is a Smart Contract?	69
7.1.1	Definition and Origins	69
7.1.2	The Vending Machine Analogy	69
7.2	Smart Contracts on Ethereum	70
7.2.1	The Ethereum Virtual Machine	70
7.2.2	Solidity: The Language of Smart Contracts	71
7.3	DVP as a Smart Contract	71
7.3.1	The Logic of Atomic Exchange	71
7.4	Limitations of Smart Contracts	74
7.4.1	The Oracle Problem	74
7.4.2	Immutability and Upgrades	74
7.4.3	Gas and Throughput	75
7.5	Smart Contracts in Enterprise Blockchains	75
7.5.1	Chaincode in Hyperledger Fabric	75
7.5.2	CorDapps in Corda	75
7.6	Summary	76

III	Designing a Settlement Blockchain	79
8	Architecture Choices	81
8.1	The Spectrum: Public to Private	81
8.1.1	Public Blockchains	81
8.1.2	Permissioned Blockchains	82
8.1.3	Private Blockchains	82
8.2	Why Public Blockchains Cannot Be Used Directly	83
8.2.1	Regulatory Requirements: Identity and Reporting	84
8.2.2	Privacy of Order Flow	84
8.2.3	Throughput and Latency	84
8.3	Enterprise Blockchain Platforms	85
8.3.1	Hyperledger Fabric	85
8.3.2	R3 Corda	86
8.3.3	ConsenSys Quorum / Hyperledger Besu	87
8.3.4	Canton (Digital Asset / DAML)	88
8.4	Choosing the Right Platform	89
8.4.1	Decision Criteria	89
8.4.2	A Comparison Matrix	90
8.4.3	The Build-versus-Join Decision	90
8.5	Summary	91
9	Tokenizing Securities and Cash	93
9.1	What Is Tokenization?	93
9.1.1	The Concert Ticket Analogy	93
9.1.2	Tokenization versus Dematerialization	94
9.1.3	The Tokenization Spectrum	94
9.2	Security Tokens	95
9.2.1	What Makes a Security Token	95
9.2.2	ERC-20 and Its Limits	96
9.2.3	ERC-1400: The Security Token Standard	96
9.2.4	ERC-3643 (T-REX): On-Chain Compliance	97
9.3	Tokenizing Cash: The Other Leg	98
9.3.1	The Cash Leg Problem	99
9.3.2	Stablecoins	99
9.3.3	Tokenized Deposits	100
9.3.4	Wholesale Central Bank Digital Currencies	100

9.4	Tokenization and DVP	101
9.4.1	On-Chain Atomic Settlement	101
9.4.2	Cross-Ledger DVP: The Interoperability Problem	101
9.5	Summary	103
10	The Regulatory Framework	105
10.1	The Regulatory Landscape	105
10.1.1	Regulation as a Specification, Not an Obstacle	105
10.1.2	The Key Regulatory Bodies	106
10.2	MiFID II and Trade Reporting	106
10.2.1	Key Requirements	106
10.2.2	Blockchain as a Compliance Tool	107
10.3	CSDR and Settlement Discipline	108
10.3.1	Settlement Finality Under CSDR and the SFD	108
10.3.2	The Settlement Discipline Regime	108
10.3.3	Licensing as a CSD	109
10.4	The EU DLT Pilot Regime	109
10.4.1	What It Allows	110
10.4.2	Who Has Used It	110
10.5	MiCA and Digital Assets	111
10.5.1	Scope and Key Provisions	111
10.5.2	Implications for Settlement	112
10.6	Designing for Compliance	112
10.7	Summary	114
11	Governance and Participants	115
11.1	The Governance Challenge	115
11.1.1	Who Runs the Network?	115
11.1.2	The Consortium Model	116
11.2	Node Architecture and Participants	117
11.2.1	Validator Nodes	117
11.2.2	Observer Nodes	118
11.2.3	The Role of the CSD	118
11.3	Rules and Amendment Procedures	119
11.3.1	The Network Rulebook	119
11.3.2	Protocol Upgrades	120
11.3.3	Dispute Resolution	120

11.4 Real-World Governance Models	121
11.4.1 The Finality Model	121
11.4.2 The Canton Network	122
11.5 Summary	124
 IV Real-World Implementations	 125
 12 What Has Been Built	 127
12.1 Overview of the Landscape	127
12.2 DTCC and Digital Securities Management	128
12.2.1 Background	128
12.2.2 Architecture	128
12.2.3 Results and Evolution	129
12.3 Euroclear Digital Securities Issuance (DSI)	129
12.3.1 Background and Architecture	129
12.3.2 Results	130
12.4 SIX Digital Exchange (SDX)	130
12.4.1 Background	130
12.4.2 Architecture	131
12.4.3 Results	131
12.5 HSBC Orion	131
12.6 Broadridge Distributed Ledger Repo (DLR)	132
12.7 The ASX CHESS Replacement: A Cautionary Tale	133
12.8 Lessons Learned	134
12.8.1 What Works	135
12.8.2 What Does Not Yet Work at Scale	135
12.9 Summary	136
 13 Limitations in a Financial Context	 139
13.1 Latency versus High-Frequency Trading	139
13.1.1 The Speed Confusion	139
13.1.2 Is T+0 Always Desirable?	140
13.2 Scalability	141
13.2.1 Transaction Throughput	141
13.2.2 Layer 2 Solutions	142
13.3 Confidentiality and Front-Running	143

13.3.1	The Transparency Paradox	143
13.3.2	Zero-Knowledge Proofs	143
13.4	Interoperability	144
13.4.1	Legacy Systems Integration	144
13.4.2	Cross-Chain Settlement	145
13.5	Legal and Operational Risks	146
13.5.1	Smart Contract Bugs	146
13.5.2	Key Management	147
13.5.3	Legal Uncertainty	148
13.6	Summary	148
V	Hands-On	151
14	A DVP Settlement Chain in Python	153
14.1	Overview and Design	153
14.2	Building the Data Structures	153
14.2.1	Accounts and Positions	153
14.2.2	The Transaction Record	154
14.2.3	The Block	155
14.3	The Blockchain	156
14.4	The Order Book and Matching Engine	157
14.5	The Settlement Engine: Atomic DVP	159
14.6	Running the Simulation	160
14.7	Extensions	161
15	Smart Contracts with Solidity	163
15.1	Setting Up the Environment	163
15.1.1	Prerequisites and Installation	163
15.1.2	Project Structure	163
15.2	The Security Token Contract	164
15.3	The DVP Settlement Contract	165
15.4	Testing and Deployment	169
15.4.1	Writing Tests	169
15.4.2	Deploying on a Testnet	170
15.5	Going Further	171

Epilogue: The Future of Settlement	173
15.6 Where We Are	173
15.7 The Road to T+0	174
15.8 CBDCs and Programmable Money	175
15.9 DeFi and TradFi: Convergence or Collision?	175
15.10 What the Practitioner Should Do Now	177
 Bibliography	 179
Part I — Blockchain and Distributed Systems	179
Part II — Financial Markets and Settlement	180
Part III — Primary Sources and Official Documents	181

Preface

This book was born from a simple observation made during years of teaching blockchain technology at the University of Paris-Saclay: the people who most needed to understand the subject — those working in financial infrastructure, post-trade services, and financial regulation — were consistently the least well served by the available literature.

On one side sat the purely technical literature: excellent, rigorous, but inaccessible to anyone without a computer science background. On the other side sat the business literature: enthusiastic, visionary, but so distant from the underlying mechanics that it provided no practical guidance for those who had to build or regulate real systems.

This book occupies the space between the two. It is written for the IT architect at a custodian bank who needs to understand what a distributed ledger actually does before proposing one to management. For the regulator at a central bank who must assess a DLT Pilot Regime application without being able to run the code. For the project manager at a central securities depository who is evaluating whether blockchain can reduce settlement fails. For the consultant who has been asked to explain tokenization to a board of directors.

The subject we chose as the book's backbone is settlement — the process by which a securities trade is finalized, money changes hands, and ownership is transferred. Settlement is unsexy, invisible, and absolutely critical. It is also one of the areas where the promise of blockchain is most concrete, most measurable, and most contested. Understanding why settlement is hard, what blockchain offers to fix it, and what it cannot fix, provides a complete and honest picture of the technology in its most demanding financial application.

The book is organized in five parts. **Part I** describes the problem: how settlement works today, where it fails, and what an ideal system would look like. **Part II** builds the technical foundation: distributed ledgers, cryptography, consensus mechanisms, and smart contracts, always illustrated with settlement examples. **Part III** moves to design: how to architect a settlement blockchain, tokenize assets, navigate the regulatory framework, and structure governance among competing institutions. **Part IV** examines what has actually been built: a candid assessment of the major real-world implementations, their results, and their limitations.

Part V is hands-on: complete working implementations of a DVP settlement chain in Python and in Solidity.

About the companion website. This book has a free companion website at financial-blockchain-project.com. Concepts that benefit from animation — the propagation of a block through a peer-to-peer network, the step-by-step execution of a DVP smart contract, the structure of a Merkle tree — are illustrated there with interactive diagrams. The full source code for all exercises is available for download. Lecture slides covering each chapter are freely accessible to students and educators. The website is designed to be a living reference, updated as the technology and regulation evolve.

No prior knowledge of blockchain is assumed. A basic familiarity with financial markets — what a stock is, what a trade is, roughly what a custodian does — is helpful but not required; Chapter 1 provides all the context needed. Some sections of Part II contain mathematical details at the level of modular arithmetic and hash functions; these can be skipped without loss of continuity by readers whose interest is primarily architectural or regulatory.

Abdelkader BOUSABAA

Paris, 2026

ALSO IN THIS SERIES

Post-Quantum Settlement Infrastructure

VOLUME II

Securing Financial Markets Against the Quantum Threat

Quantum computers will not merely be faster — they will break the asymmetric cryptography protecting every digital signature and TLS handshake in use today. Volume II builds the technical and strategic case for migration to the 2024 NIST post-quantum standards (ML-KEM, ML-DSA, SLH-DSA), covering lattice cryptography, hybrid transition architectures, quantum-safe DLT design, and the emerging regulatory framework from DORA to CNSA 2.0.

financial-blockchain-project.com

Blockchain for Financial Markets

VOLUME I

Financial markets settle trillions of euros each day through a chain of custodians, central securities depositories, and central counterparty clearing houses whose inner workings remain largely invisible to most participants. This volume examines what can go wrong in this system — from settlement fails to counterparty and custody risk — and builds the case for a redesigned infrastructure based on distributed ledger technology.

Starting from first principles, the book develops each component of a blockchain settlement system: the data structure, consensus mechanisms, smart contract automation, the tokenisation of securities and cash, and the governance models required for institutional adoption. Two hands-on chapters translate theory into working Python and Solidity code, available on the companion website alongside interactive diagrams and lecture slides.

Topics covered

Settlement infrastructure • DVP mechanisms • Distributed ledgers • Blockchain integrity • Consensus algorithms • Smart contracts • Tokenisation of securities • Regulatory framework • Real-world implementations • Python & Solidity code

Abdelkader Bousabaa — *University of Paris-Saclay*

Researcher and educator specialising in financial market infrastructure, distributed ledger technology, and post-quantum cryptography. This two-volume series bridges capital markets practice and the mathematics of next-generation settlement systems.