

# E-Payment Systems and Cryptocurrency Technologies

<https://course.ie.cuhk.edu.hk/~ierg4004>

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# Acknowledgements

■ The slides used in this lecture are mostly adapted from the following sources. The copyrights and contribution of the original authors are hereby acknowledged and recognized:

- ◆ **The Electronic Payment Systems course by Prof. Michael Shamos, CMU**
- ◆ World Payments Report 2019, Capgemini Research Institute
- ◆ McKinsey&Company, “Global Payments 2018: a dynamic industry continues to break new ground”, Oct 2018.
- ◆ John Hill, Fintech and the Remaking of Financial Institutions, Academic Press 2018
- ◆ Speech by Thomas J. Jordan, Chairman of the Governing board, Swiss National Bank, “How money is created by the central bank and the banking system,” Jan 16, 2018, <https://www.bis.org/review/r180118c.pdf>
- ◆ Eswar Prasad, “Central Banking in a Digital Age: Stock-taking and Preliminary Thoughts,” April 2018, [https://www.brookings.edu/wp-content/uploads/2018/04/es\\_20180416\\_digitalcurrencies.pdf](https://www.brookings.edu/wp-content/uploads/2018/04/es_20180416_digitalcurrencies.pdf)
- ◆ Vivien Lee and David Wessel, “Digital Currencies: Five big implications for central banks,” May 2018, [https://www.brookings.edu/blog/Academic Press/up-front/2018/05/21/digital-currencies-five-big-implications-for-central-banks/](https://www.brookings.edu/blog/Academic%20Press/up-front/2018/05/21/digital-currencies-five-big-implications-for-central-banks/)
- ◆ Robert E. Litan and Martin Neil Baily, Editors, Moving Money: The Future of Consumer Payments, Brookings Institution Press, 2009.
- ◆ Banking and Electronic Fund Transfer, OCDE, OCED, 1983.
- ◆ Brett King, Breaking Banks -The Innovators, Rogues, and Strategists Rebooting Banking, Wiley, 2014.

# Course Objectives

- Understand money and its movement
- Understand foreign exchange
- Learn how money is made electronic
- Learn the role of Electronic Payments in emerging economy
- Understand the technical principles and system architecture of electronic payment systems/ technologies
- Understand how major types of payment systems work; appreciate and be able to analyze and compare their risks and advantages

# Course Outline

- Introduction to Money and Banking
- Automated Clearing and Settlement
- *Quick Recap on Crypto Basics which enable Secure Payment Systems*
- Overall Landscape of E-payment Systems
- Credit Card system and protocols
- Stored-Value Facilities (SVFs), e.g. Smartcards, RFID, NFC, Octopus card
- Digital Wallet and Mobile Payment Systems
- P2P payment systems, e.g. Paypal
- Crypto-currencies and related Technologies, e.g. Blockchains, Bitcoin, Ethereum, Smart Contracts,
- Time-permitting: Central Bank Digital Currencies (CBDC), Failed examples of E-Cash/ Micro-Payment Protocols



# Lecture Outline

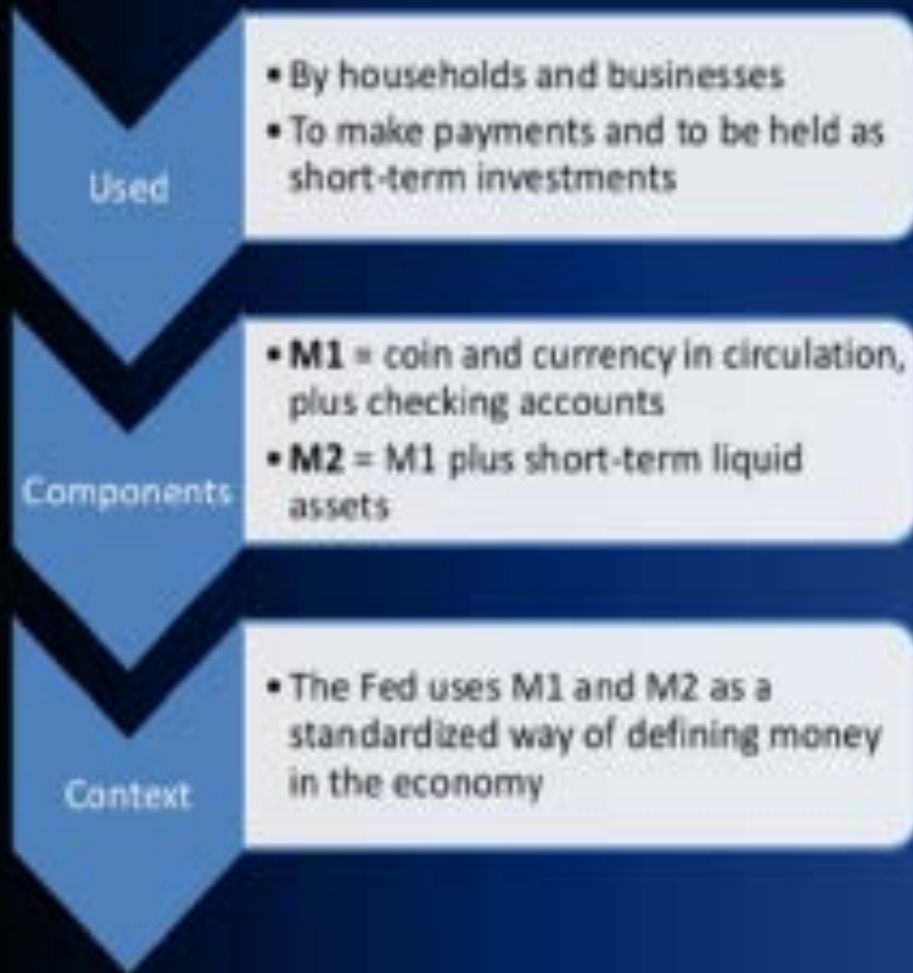
- Nature of money
- What is a payment?
- What is a payment system?
- Desirable properties of money
- Payment system requirements
- Payment risks
- What banks do
- Foreign exchange

What is Money ?

# What is Money ?

- A Medium of Exchange
- A Unit of Account (pricing of services and goods)
- Storage of Value

# Money Supply in the U.S.



**M1 and M2**  
(\$trillions, nonseasonally adjusted)

Source: Federal Reserve Board



As a share of the total values shown above, M1 dropped from 26% in 1980 to 20% in 2010.<sup>1</sup>

1. See PowerPoint file for technical note.

# U.S. Money Supply - Components

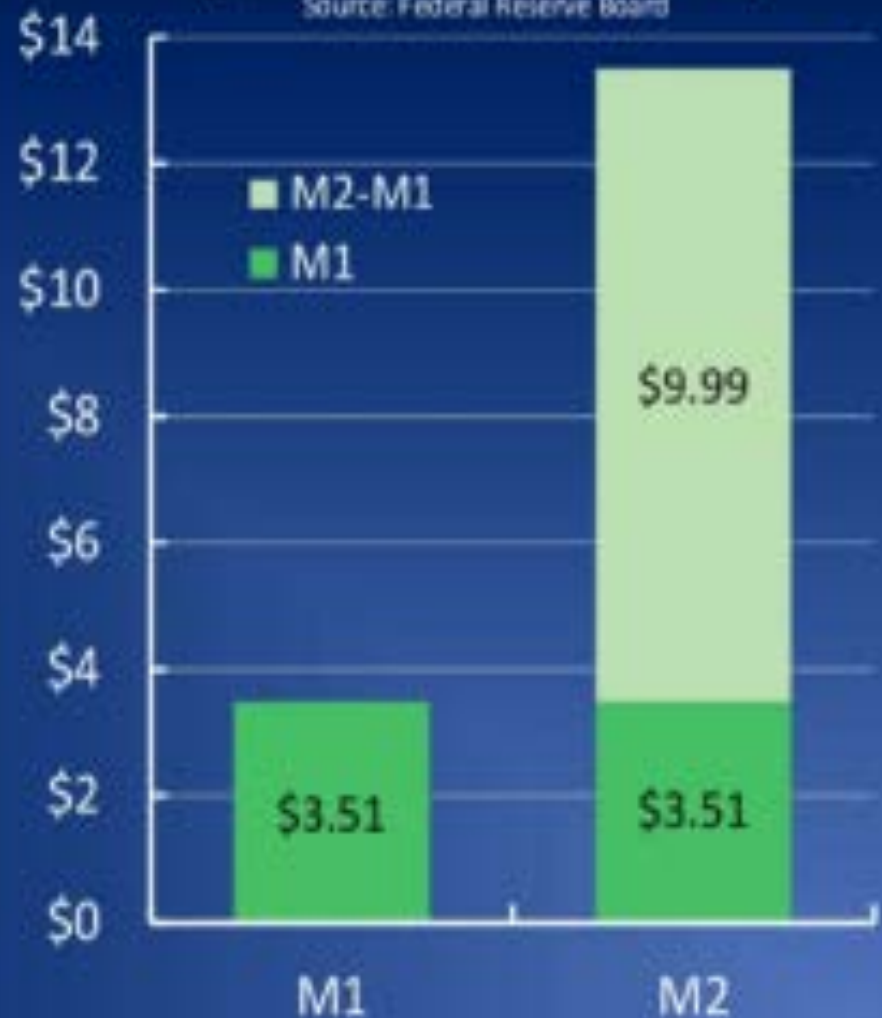
## M2

- Savings Deposits
- Time Deposits
- Certain CDs
- Money Market Deposit Accounts
- Money Market Mutual Funds
- Includes M1

## M1

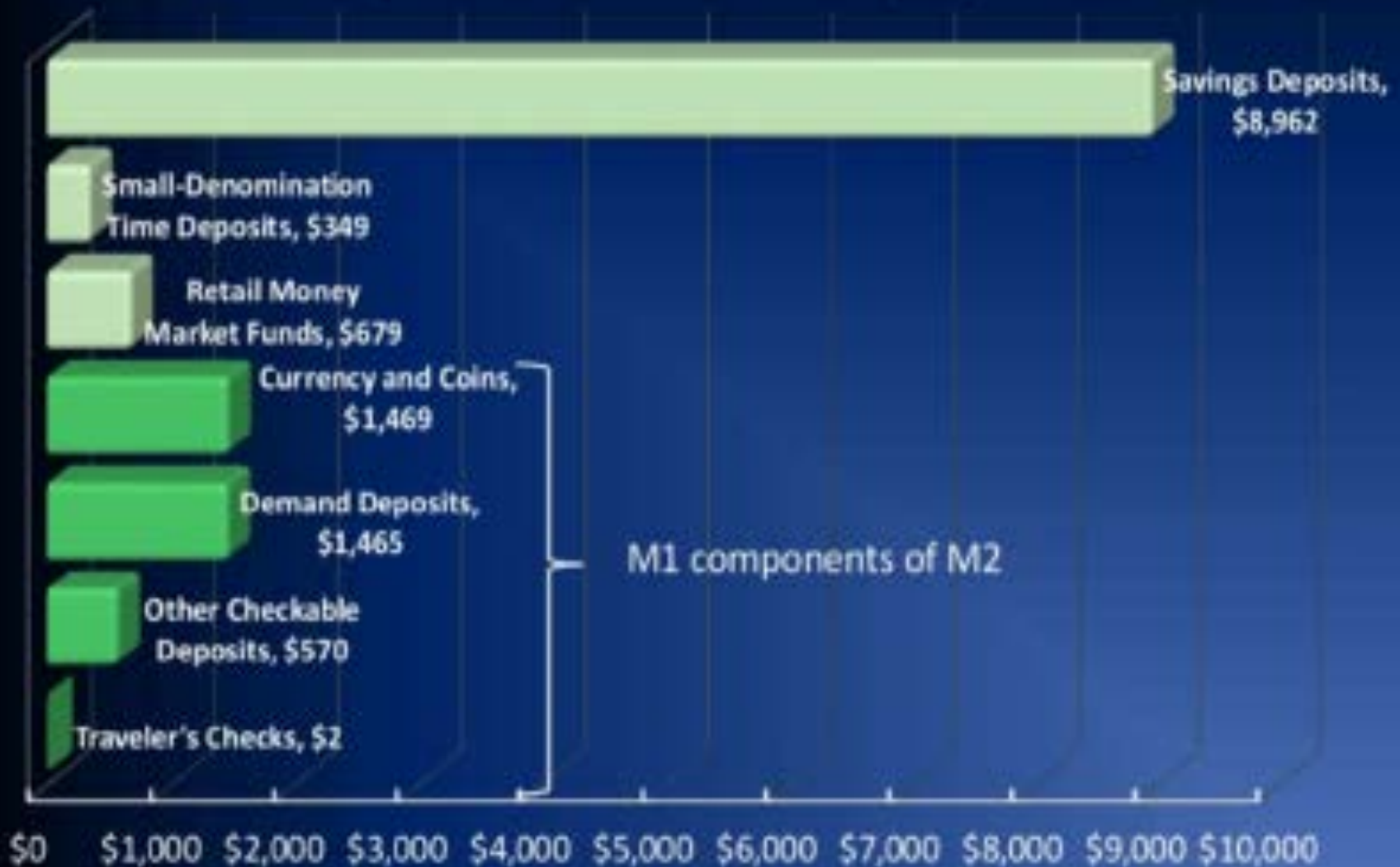
- Coin
- Currency
- Demand Deposits
- Travelers Checks

May 2017  
(\$trillions, seasonally adjusted)  
Source: Federal Reserve Board



# M2 in Details

May 2017 (\$billions, seasonally adjusted)



Source: Federal Reserve Board 7/6/17 data release

Note: Components may not add to totals due to rounding

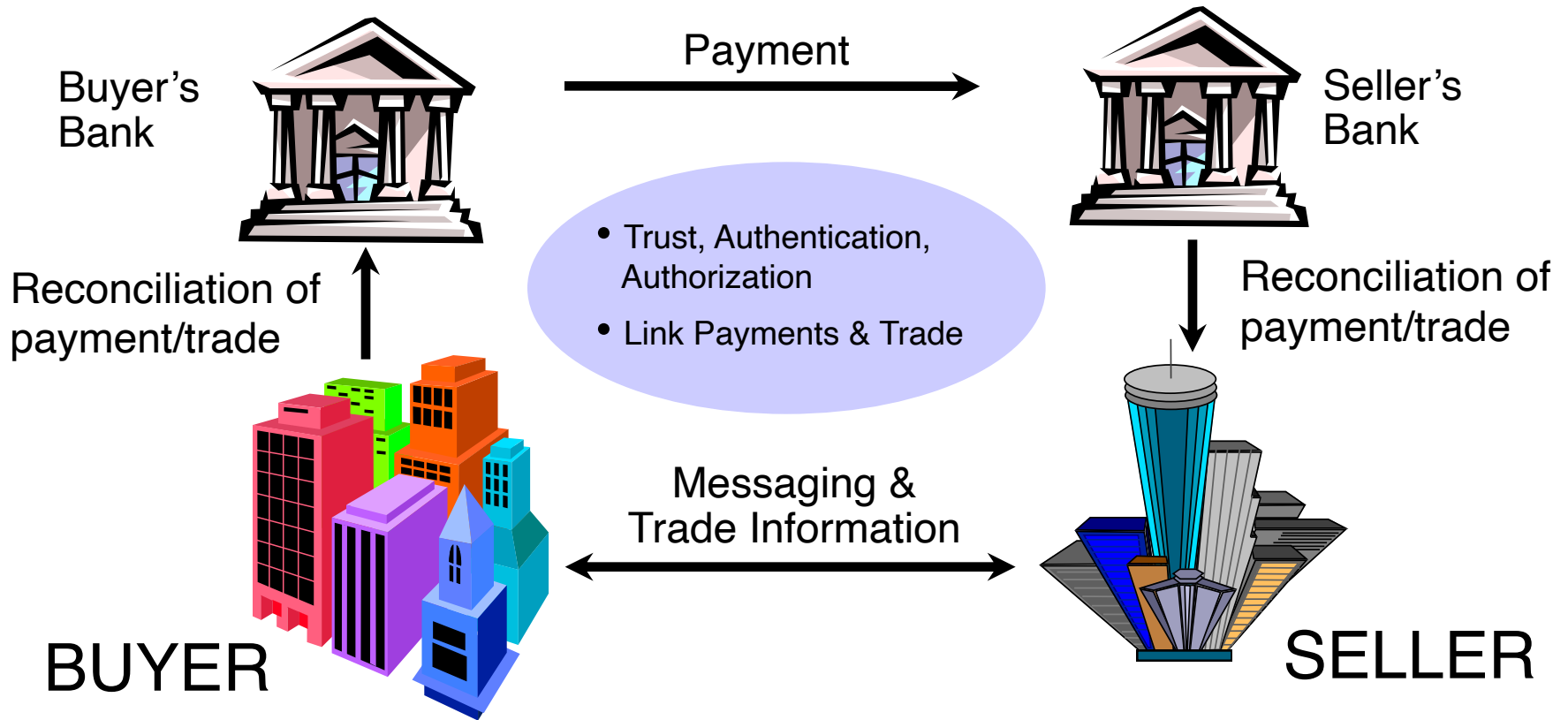


# How Much Money got exchanged ?

- U.S. interbank payments: 1.5 trillion USD per day (2015)
- World foreign exchange: 6.6 trillion USD per day (2019)
- World stock trading volume: ~100 trillion USD in 2018
- US Stock trading volume per year (2018): 33 trillion USD
  - ◆ NYSE had \$169 billion traded daily on average in 2013
- Global Credit Card transactions values: 71 billion USD in 2012
- Paypal Total Payment Volume in 2019: > 650 billions USD
- China's Mobile Payment market reached 7.1 trillion USD in 2018Q4.
- Total SVF transaction value in HK: 5 billion USD in 2018Q2



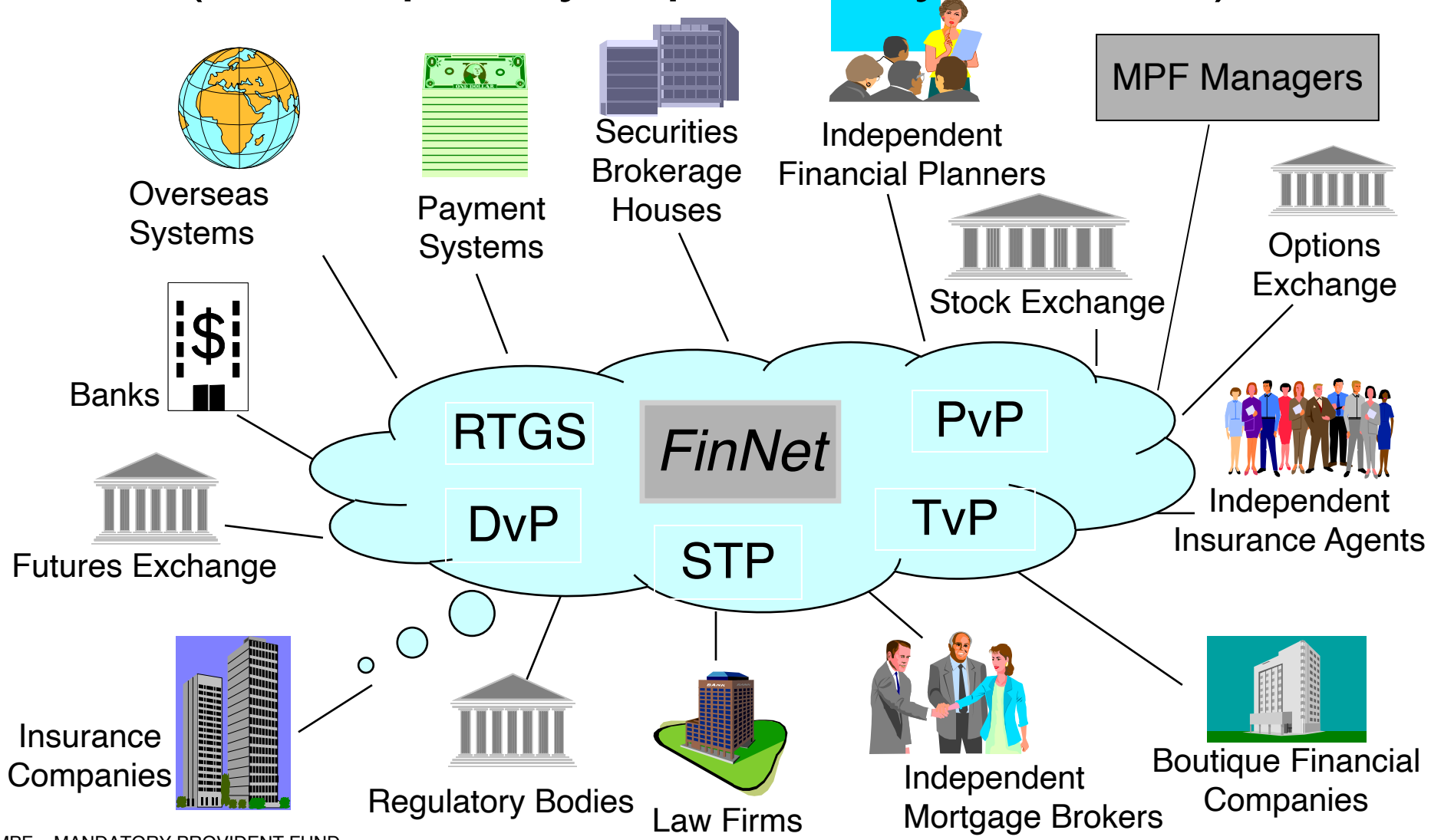
# Fundamental B2B Payment Problem



- How is authentication performed?
- How is payment made?
- How is messaging accomplished?
- How is information reconciled?
- How are exceptions handled?

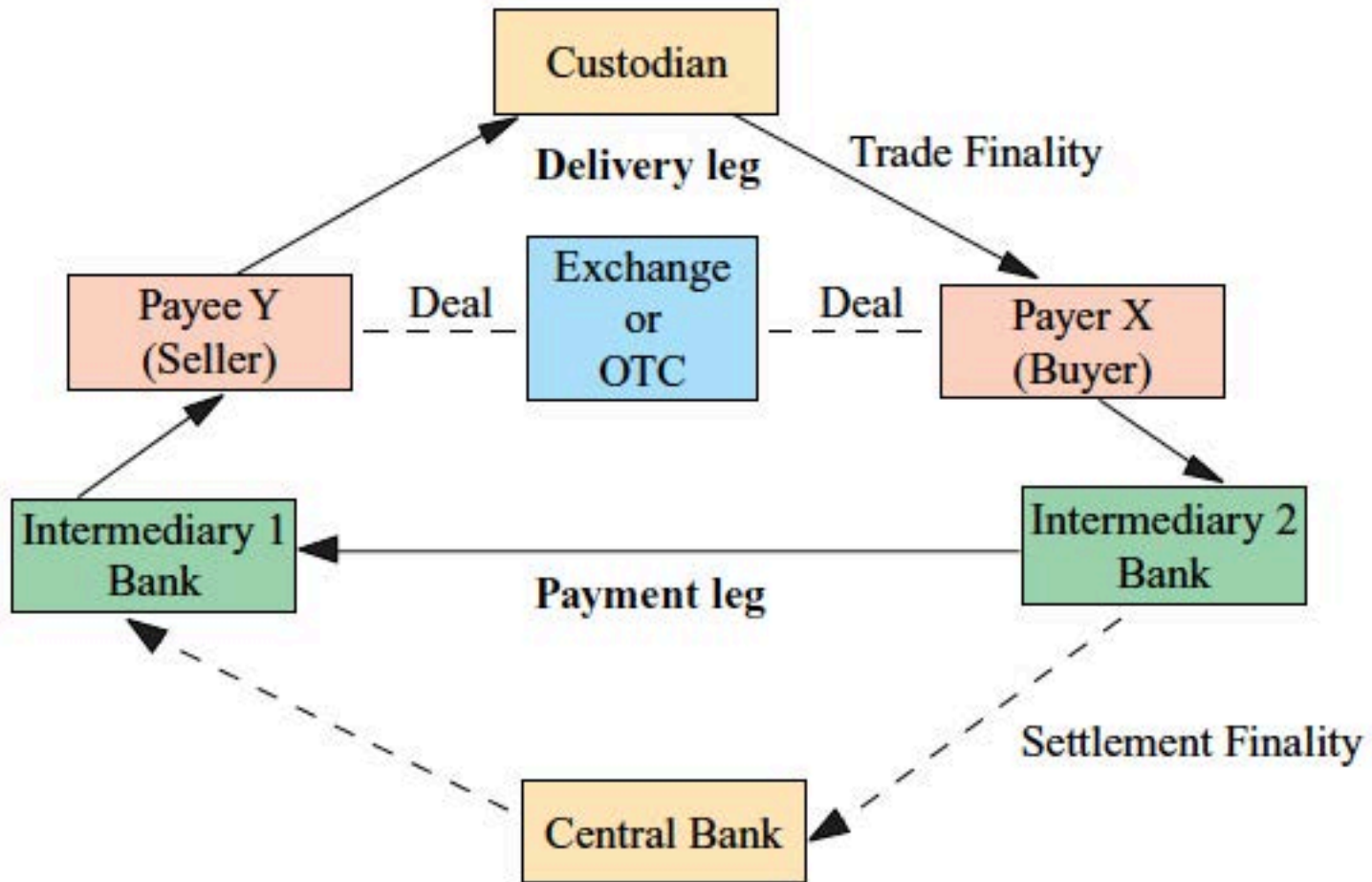


# FinNet - Financial Network for Hong Kong (subsequently replaced by SDNet/2)

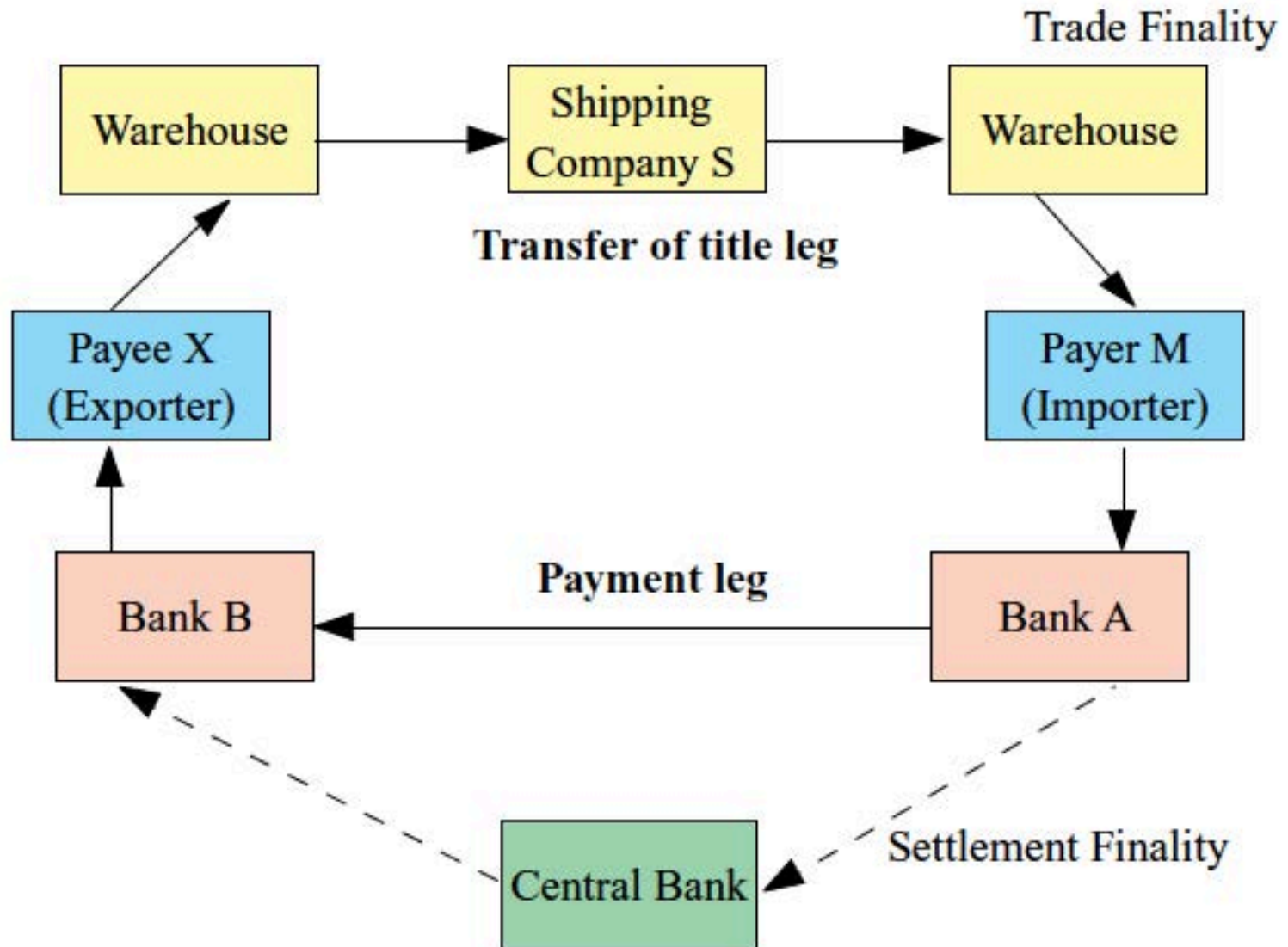


MPF = MANDATORY PROVIDENT FUND  
 STP = STRAIGHT-THROUGH PROCESSING  
 TvP = TRANSFER V. PAYMENT

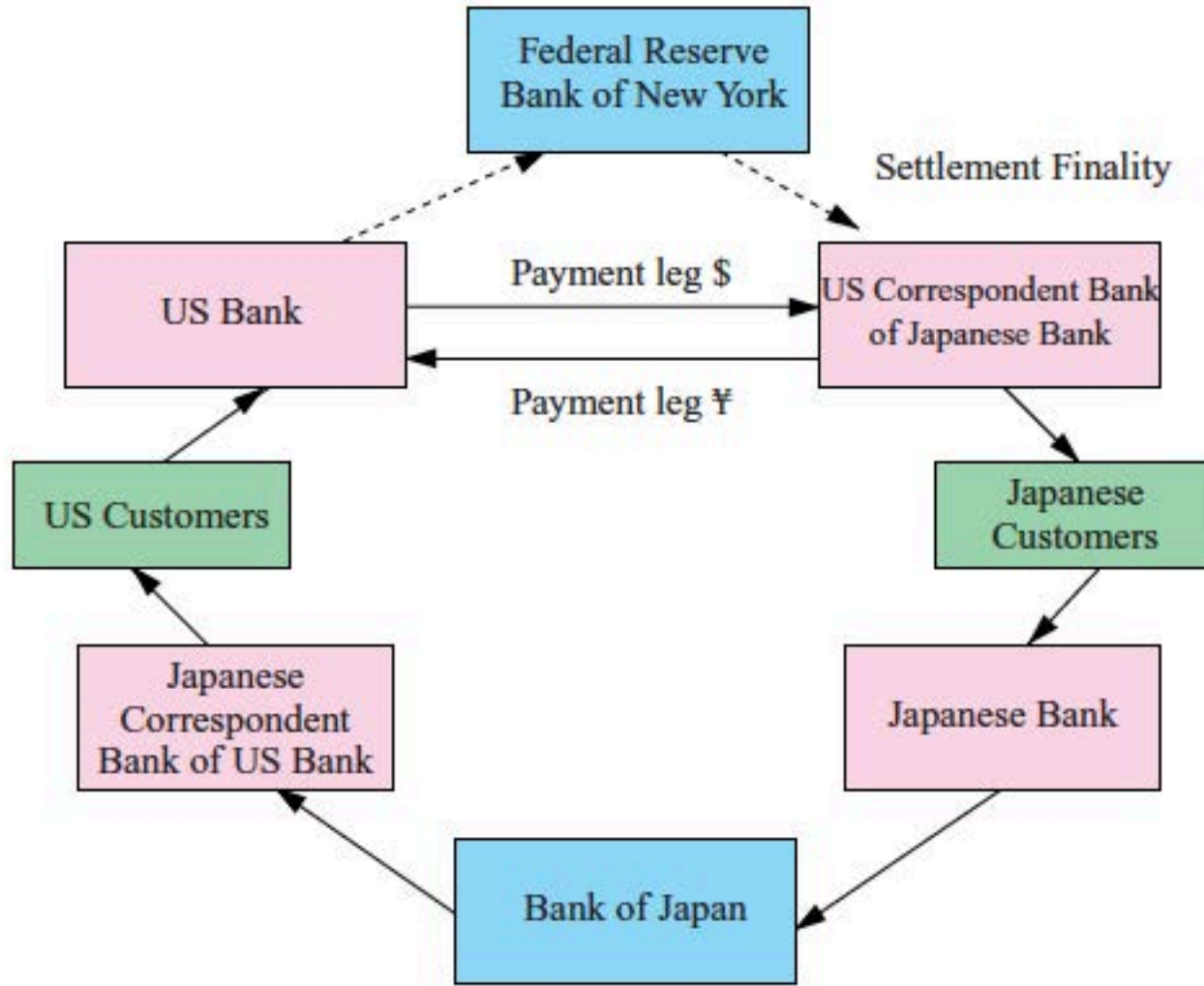
**Chart 3: Delivery versus Payment Legs (DvP)**



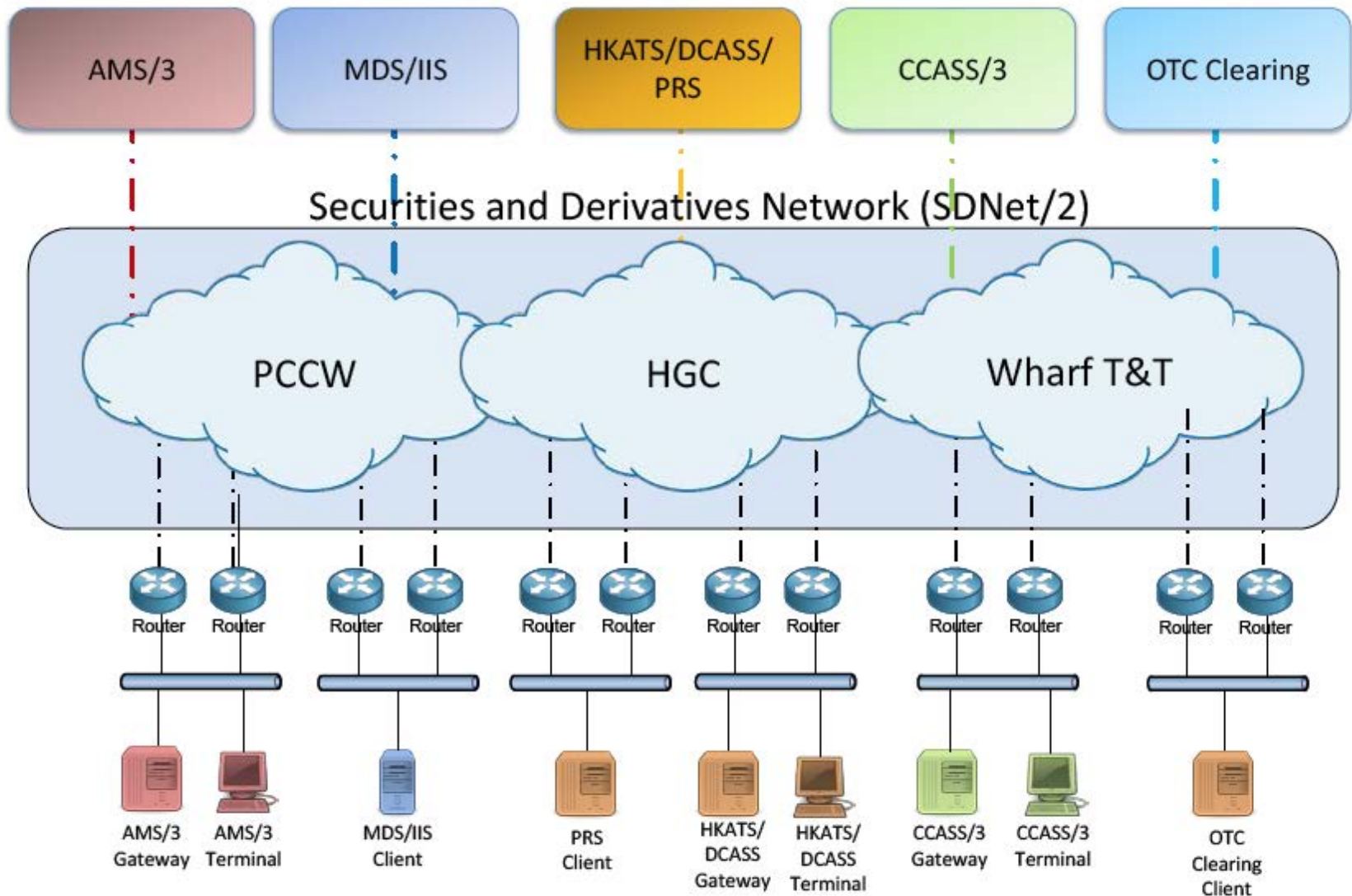
**Chart 6: Transfer of title versus Payment Legs (TvP)**



**Chart 5: Payment versus Payment Legs (PvP)**



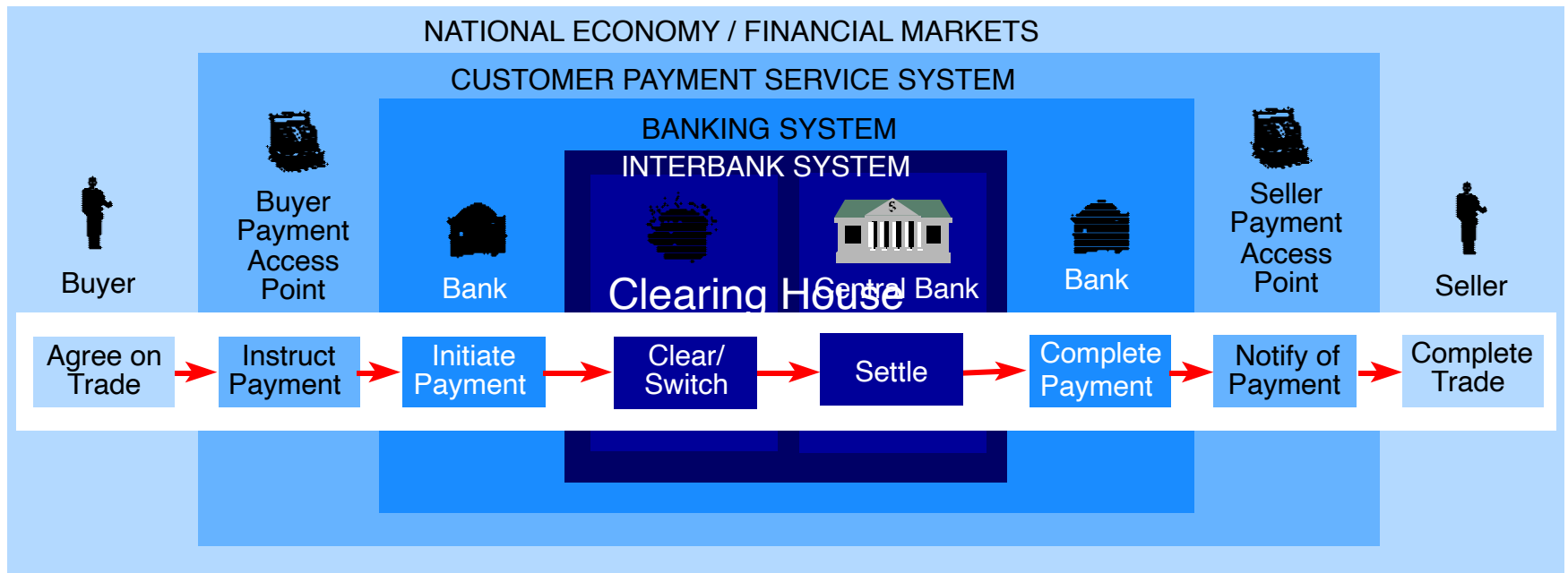
# The Security and Derivatives Network SDNet/ from the Hong Kong Exchange



(Remark: HGC does not provide OTC connection Service)

# The Payment Process

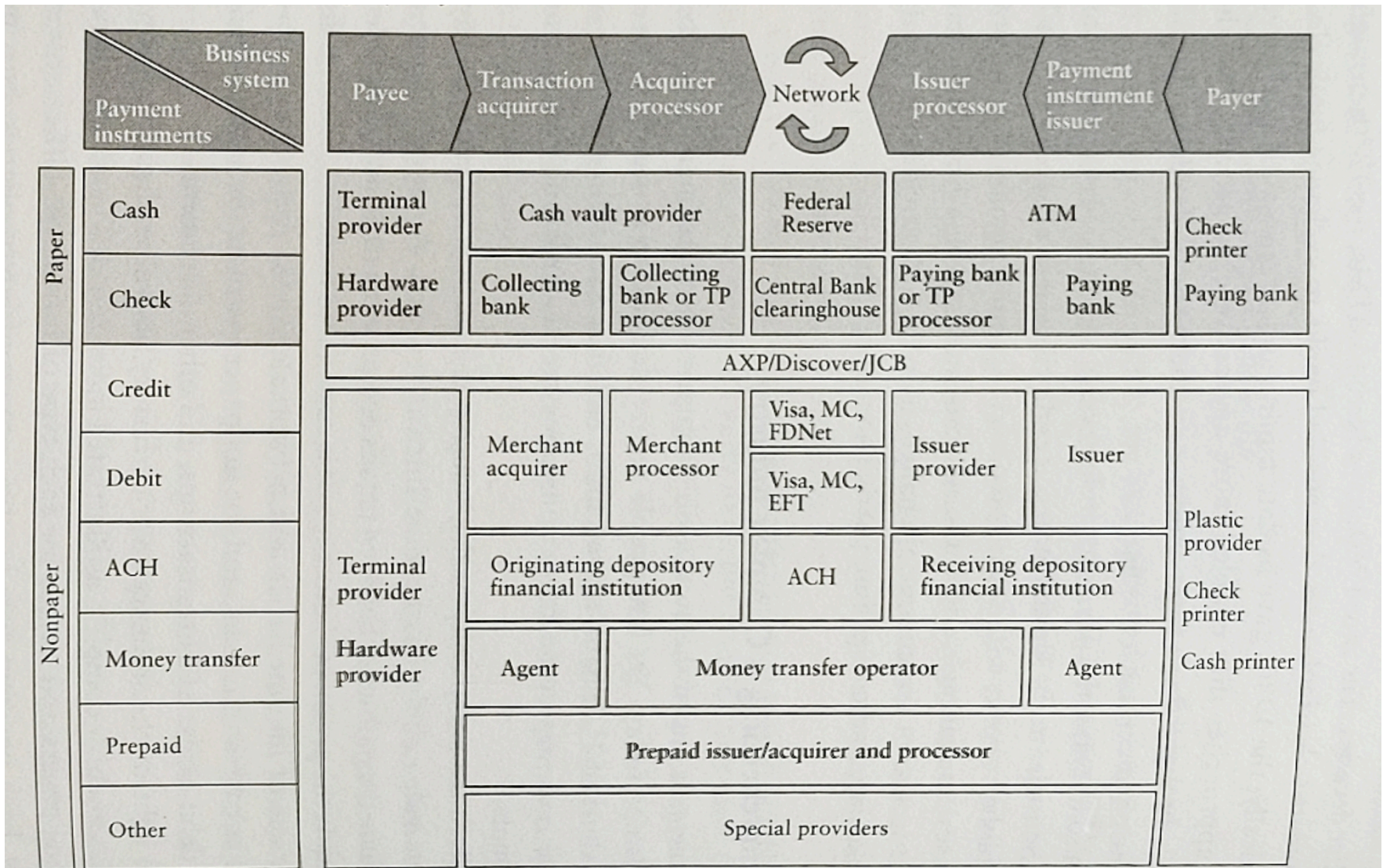
Payment is just ONE component of eCommerce,  
but a VERY IMPORTANT component



SOURCE: PHILIP TROMP, [PERAGO.COM](http://PERAGO.COM)



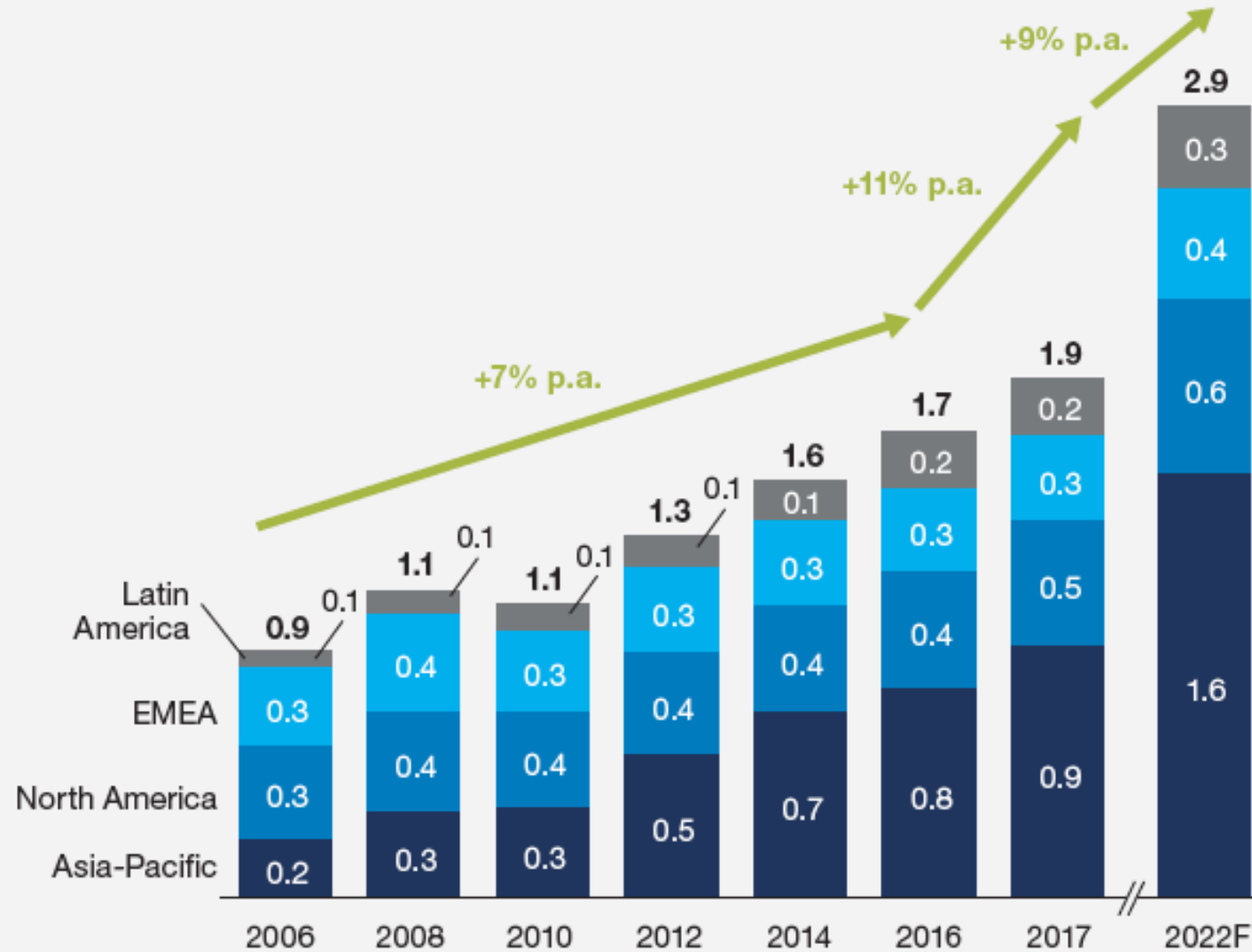
# Complexity of Payments Value Chain



# Global Payment Revenues

## Global payments revenue

\$ trillion



2012-17  
CAGR

2017-22  
CAGR

%

%

13

8

0

6

5

7

12



11

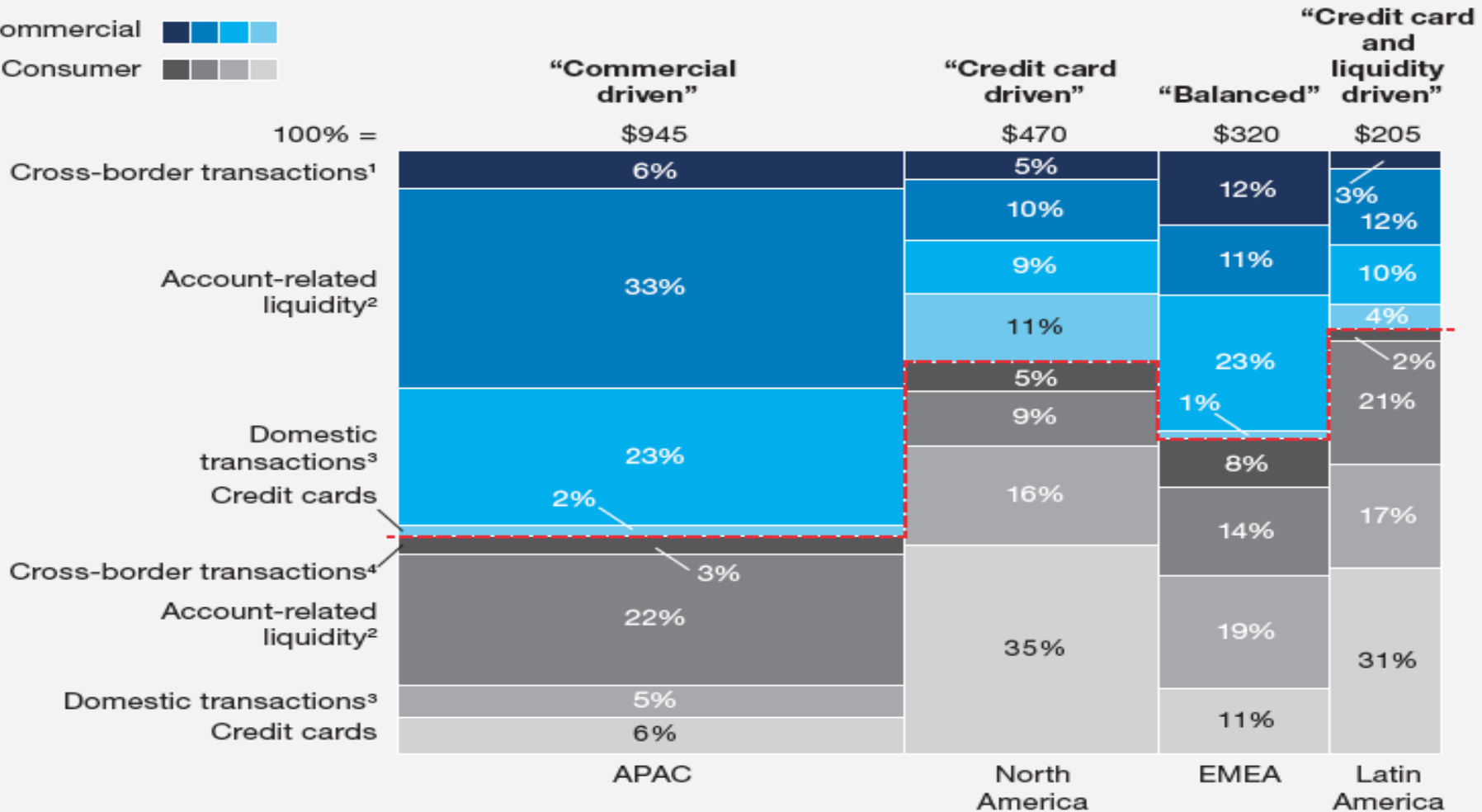


# Global Payment Revenue Pool

## Payments revenue, 2017

\$ billion

Commercial   
 Consumer 



<sup>1</sup> Trade finance and cross-border payments services (B2B, B2C).

<sup>2</sup> Net interest income on current accounts and overdrafts.

<sup>3</sup> Fee revenue on domestic payments transactions and account maintenance (excluding credit cards).

<sup>4</sup> Remittance services and C2B cross-border payments services.

# Payment Revenue Growth by Country

Growth rate of electronic transactions, 2016-17

%

● Emerging countries

● Developed countries

○ Size of bubble denotes payments revenue in 2017



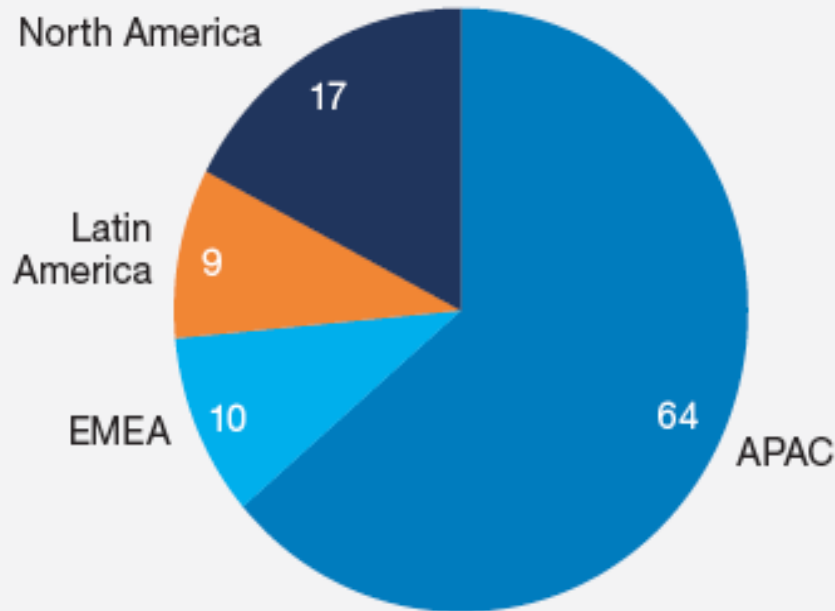
Payments revenue growth rate, 2016-17

%

# Payment Revenue Growth Decomposition

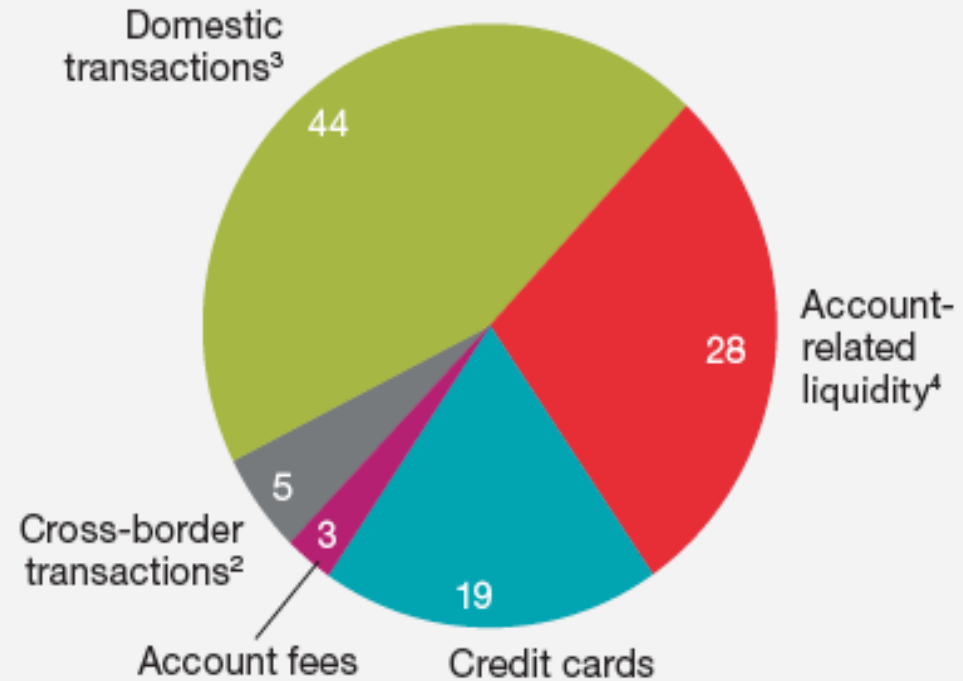
**Payments revenue growth decomposition<sup>1</sup>, 2017-22**

% (100% = \$1,022 billion)



**Payments revenue growth decomposition<sup>1</sup>, 2017-22**

% (100% = \$1,022 billion)



<sup>1</sup> At fixed 2017 USD exchange rates.

<sup>2</sup> Trade finance and cross-border payments services, including remittance services.

<sup>3</sup> Fee revenue on domestic payments transactions.

<sup>4</sup> Net interest income on current accounts and overdrafts.

# Global Transaction Banking Revenues

Global transaction banking revenues are estimated at nearly \$1 trillion, or 43 percent of wholesale banking revenues.

## Core global transaction banking products

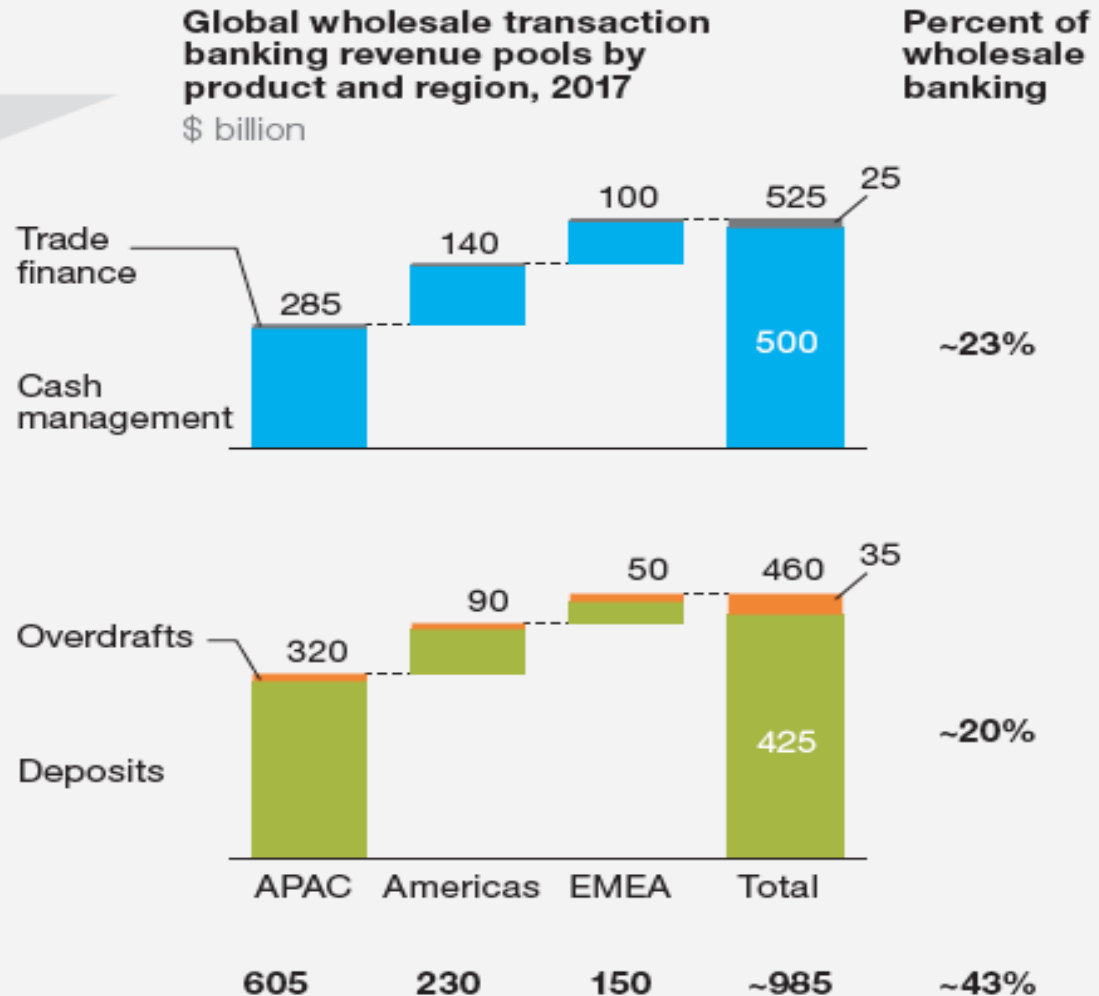
**Trade finance:** All documentary business for international trade, including letter of credit confirmation.

**Cash management:** domestic and cross-border payments, including liquidity management.

## Other working capital instruments

**Overdrafts:** Pre-arranged or unarranged overdrafts at domestic banks.

**Deposits:** C/As and transactional savings deposits at domestic banks.

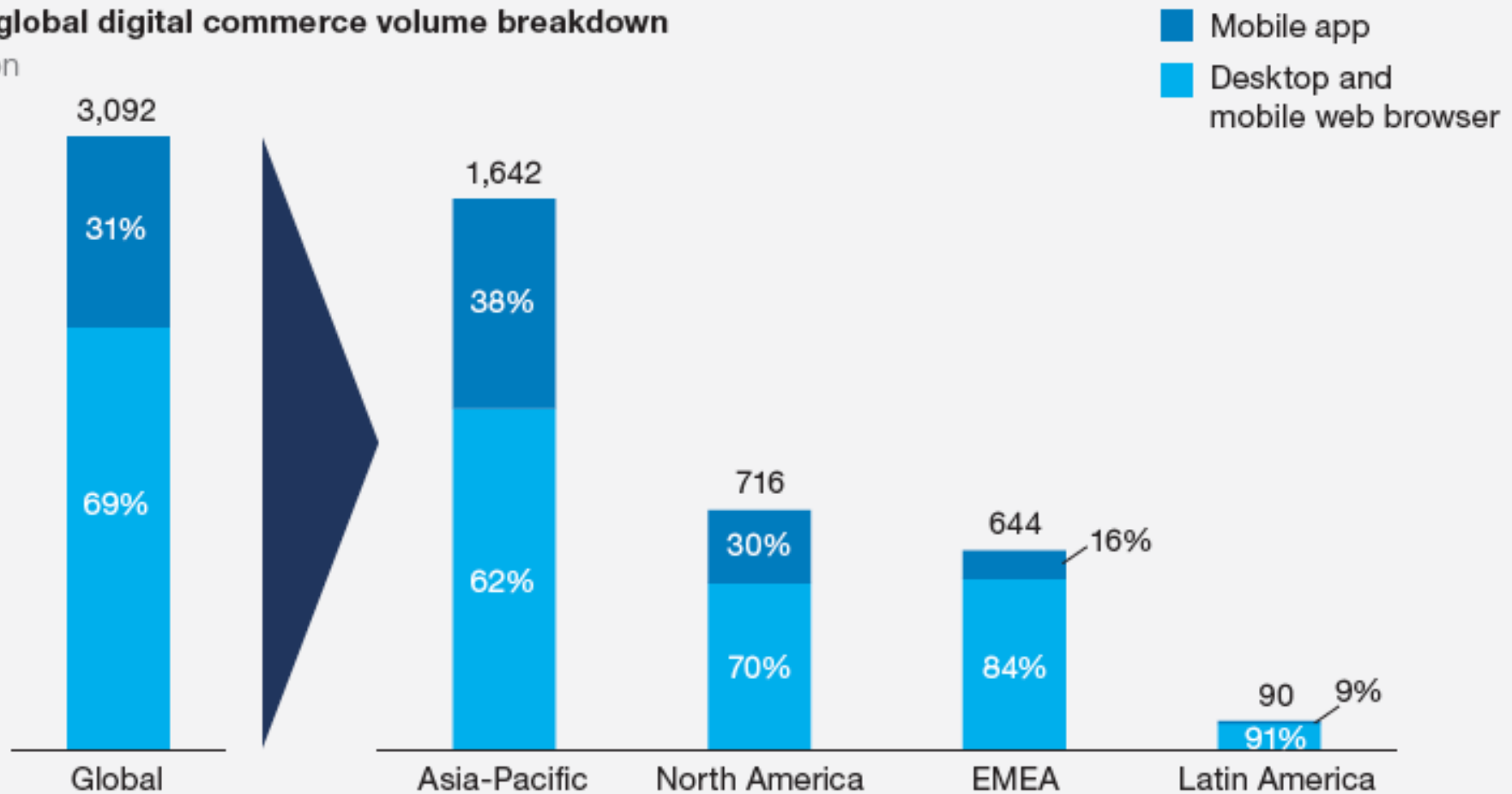


# Mobile Apps Impact on Global Digital Commerce

Mobile apps accounted for more than 30 percent of global digital commerce volume in 2017.

## 2017 global digital commerce volume breakdown

\$ billion

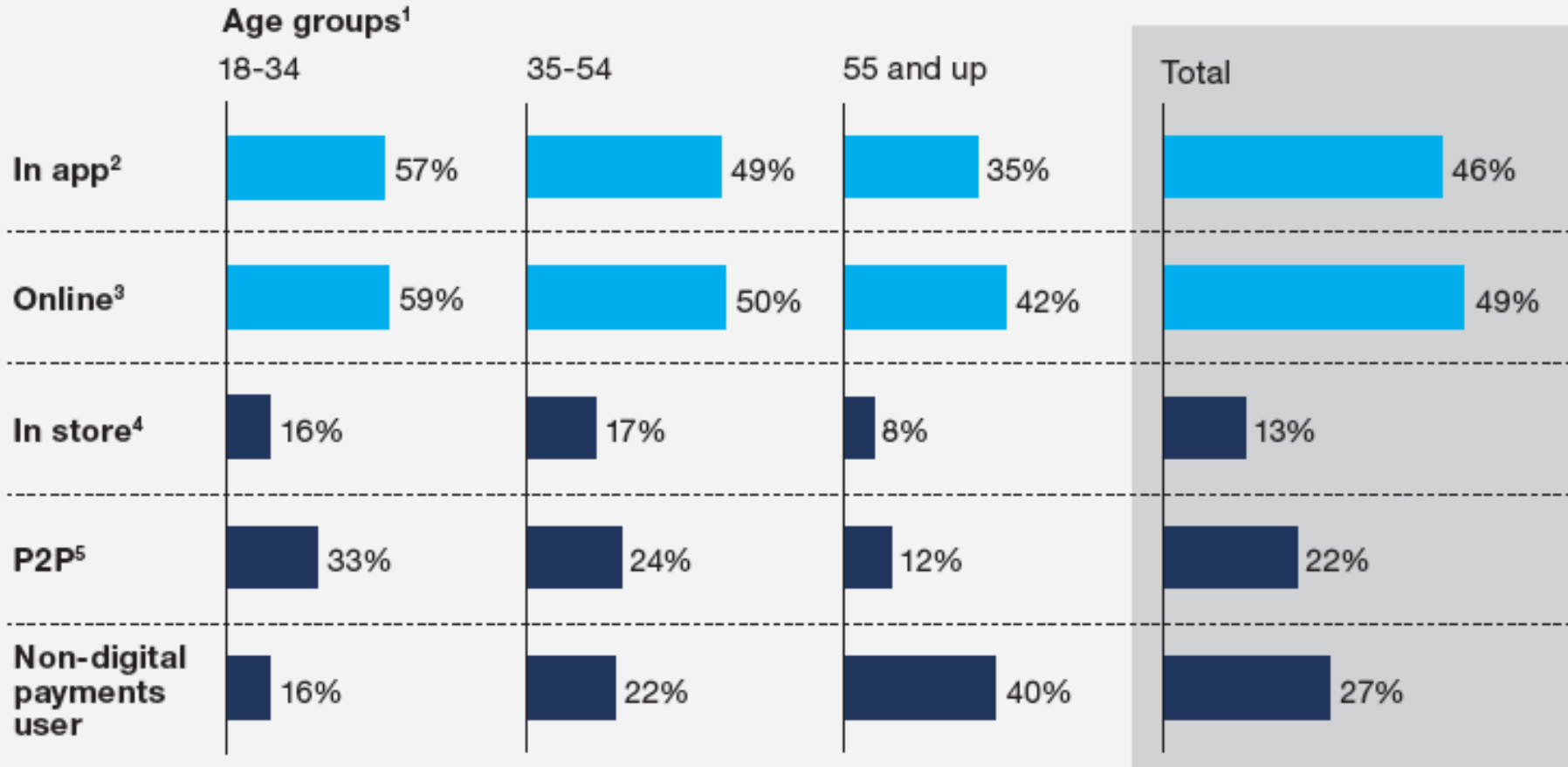


Source: GCI Analytics

# Digital Payment Penetration Rate in US

In the past 12 months, have you performed any of these activities?

% of respondents, US



<sup>1</sup> N= 18-34 (283); 35-54 (396); 55 and up (422); total (1,101)

<sup>2</sup> Buy things and/or pay for services using a retailer's app on my device (e.g., Amazon, Starbucks, Uber).

<sup>3</sup> Buy things through a website on my device (e.g., Target.com).

<sup>4</sup> Use my device to pay at retail locations by interacting with a terminal (e.g., Apple Pay, Android Pay, Samsung Pay, LevelUp).


<sup>5</sup> Transfer money to friends, family, or acquaintances through an app (e.g., PayPal, Venmo, Square Pay).

# Development of Money

- Definition: “*something generally accepted as a medium of exchange, a measure of value, or a means of payment.*”

## Monetary History:

ABSTRACTION

- Barter (direct exchange of goods)
  - Medium of exchange (arrowheads, salt)
  - Coins (gold, silver)
  - Tokens (paper)
  - Notational money (bank accounts)
  - Dematerialized schemes (pure information)
- } NEED BANKS
- 

# Barter

- Direct exchange of goods and services -- possible when production exceeds individual needs
  - Problem: “double coincidence of wants”
    - ◆ Trade a bicycle for a cow
    - ◆ Alice must have a bicycle and want a cow
    - ◆ Bob must have a cow and want a bicycle
- } UNLIKELY
- But: Internet allows rapid discovery of wants
  - Problem: remote barter requires an escrow (or risk)
  - Problem: outside the monetary and tax systems
  - When money is not trusted, barter returns
  - Electronic Barter Systems/ Online services exist:
    - ◆ <https://electronics.howstuffworks.com/family-tech/tech-for-parents/online-bartering-websites-tips.htm>



# Types of Money: Fiduciary vs. Scriptural

- Fiduciary money (fiat money, legal tender)
  - ◆ Issued by a central (government) bank
  - ◆ Has real “discharging power” (to discharge debts)
  - ◆ Cannot be refused
- Scriptural money (not legal tender)
  - ◆ Money not issued by a central bank
  - ◆ Examples: bank accounts, travelers cheques, gift certificates, Octopus
  - ◆ Discharging power based on trust in issuer
  - ◆ Can be refused

# Types of Money: Token vs. Notational

- Token money
  - ◆ Represented by a physical article (e.g. cash)
  - ◆ Can be lost
- Notational money
  - ◆ Examples: bank accounts, frequent flyer miles
  - ◆ Electronic (scriptural) money: wide recognition
  - ◆ Jeton = electronic token with limited recognition
- Hybrid money
  - ◆ Check/ Cheque
  - ◆ Telephone card (carries Jetons for future service)

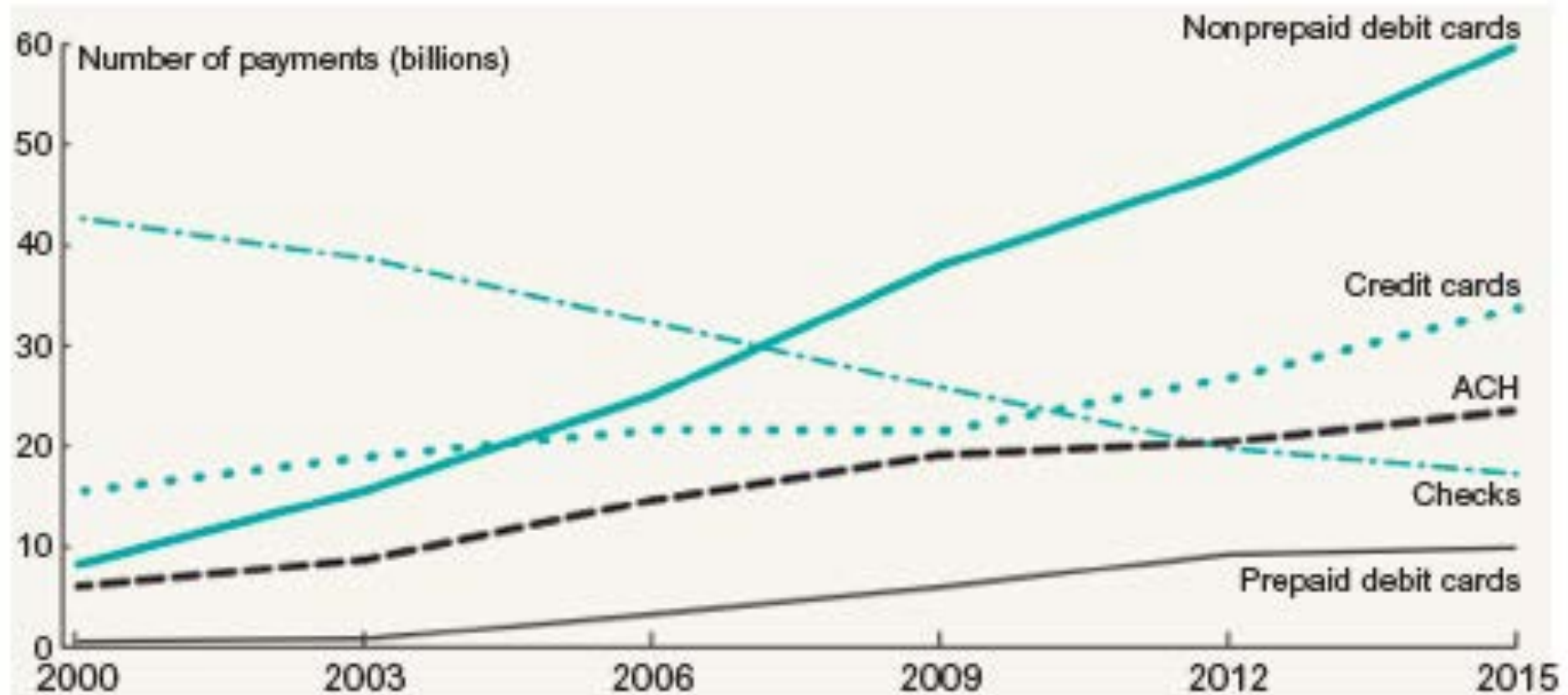
# The Money Matrix

|                   | <b>TOKEN</b>                                                                                 | <b>NOTATIONAL</b>                                                                             | <b>HYBRID</b>                                                                               |
|-------------------|----------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------|
| <b>FIDUCIARY</b>  | <ul style="list-style-type: none"><li>• CASH</li><li>• GOVERNMENT BEARER BOND</li></ul>      | <ul style="list-style-type: none"><li>• ACCOUNT WITH CENTRAL BANK</li></ul>                   | <ul style="list-style-type: none"><li>• GOVERNMENT CHECK</li></ul>                          |
| <b>SCRIPTURAL</b> | <ul style="list-style-type: none"><li>• CERTIFIED CHECK</li><li>• TRAVELER'S CHECK</li></ul> | <ul style="list-style-type: none"><li>• BANK ACCOUNT</li><li>• FREQUENT FLYER MILES</li></ul> | <ul style="list-style-type: none"><li>• PERSONAL CHECK</li><li>• GIFT CERTIFICATE</li></ul> |

# Specialized Payment Instruments

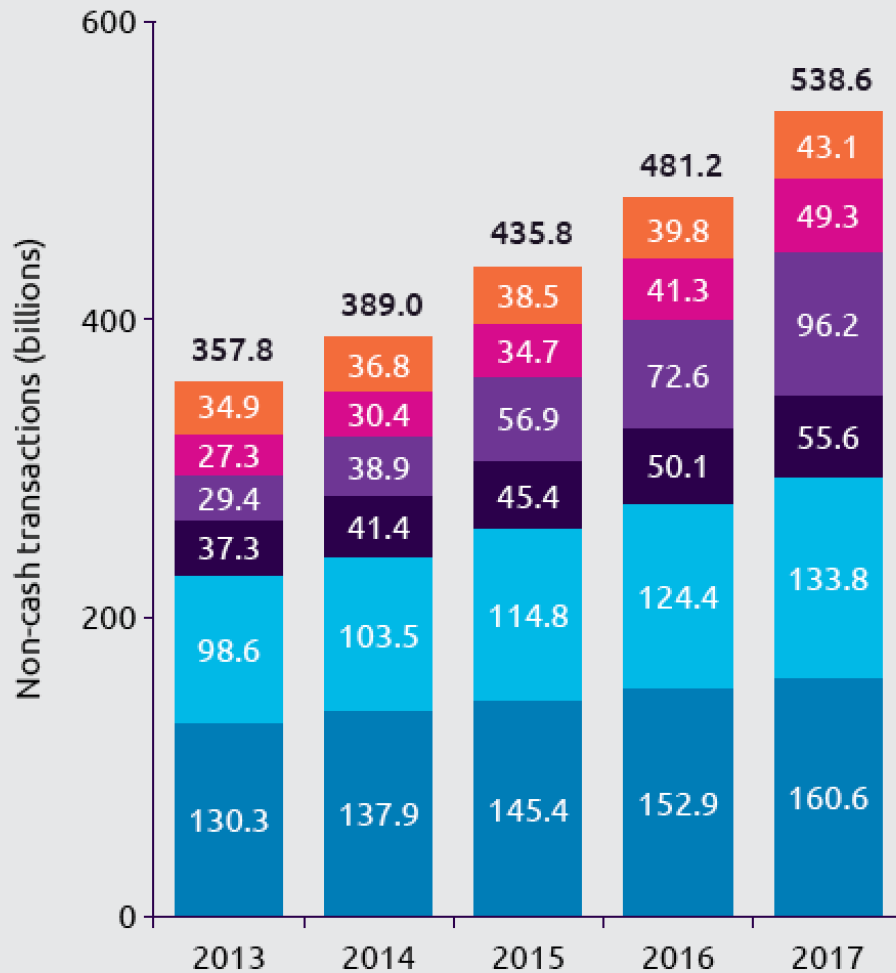
- Money order (allows named person to claim money)
- Traveler's check (limited to one spender)
- Gift certificate (limited to one merchant)
- Coupons, food stamps (limited to certain goods)
- Bill of Lading (sight draft), Letter of Credit
  - ◆ Purpose: atomicity (connect goods and payment)

# Trends in Non-Cash Payments



**Figure 3.4** Trends in noncash payments 2000–2015, by number. *Source: FRB. Note: Prepaid debit card includes general purpose, private label, and electronic benefit transfer.*

# World-wide Non-cash Transactions by regions



|                             | CAGR<br>(2013–17) | Growth<br>(2015–16) | Growth<br>(2016–17) |                       |
|-----------------------------|-------------------|---------------------|---------------------|-----------------------|
| <b>Global</b>               | <b>10.8%</b>      | <b>10.4%</b>        | <b>12.0%</b>        |                       |
| Latin America               | 5.4%              | 3.4%                | 8.3%                | } Developing<br>22.6% |
| MEA                         | 15.9%             | 19.0%               | 19.3%               |                       |
| Emerging Asia               | 34.6%             | 27.6%               | 32.5%               |                       |
| Mature Asia-Pacific         | 10.5%             | 10.4%               | 11.0%               |                       |
| Europe (Including Eurozone) | 7.9%              | 8.4%                | 7.6%                | } Mature<br>6.9%      |
| North America               | 5.4%              | 5.1%                | 5.1%                |                       |

# Ecommerce Payment Ranges

| AMOUNTS IN USD | Minimum Transaction Value | Typical Transaction Value | Maximum Transaction Value |
|----------------|---------------------------|---------------------------|---------------------------|
| Macro          | \$5.00                    | \$50.00                   | $\infty$                  |
| Mini           | \$0.10                    | \$1.00                    | \$10.00                   |
| Micro          | \$0.001                   | \$0.01                    | \$.10                     |

SOURCE: COMPAQ CORP.

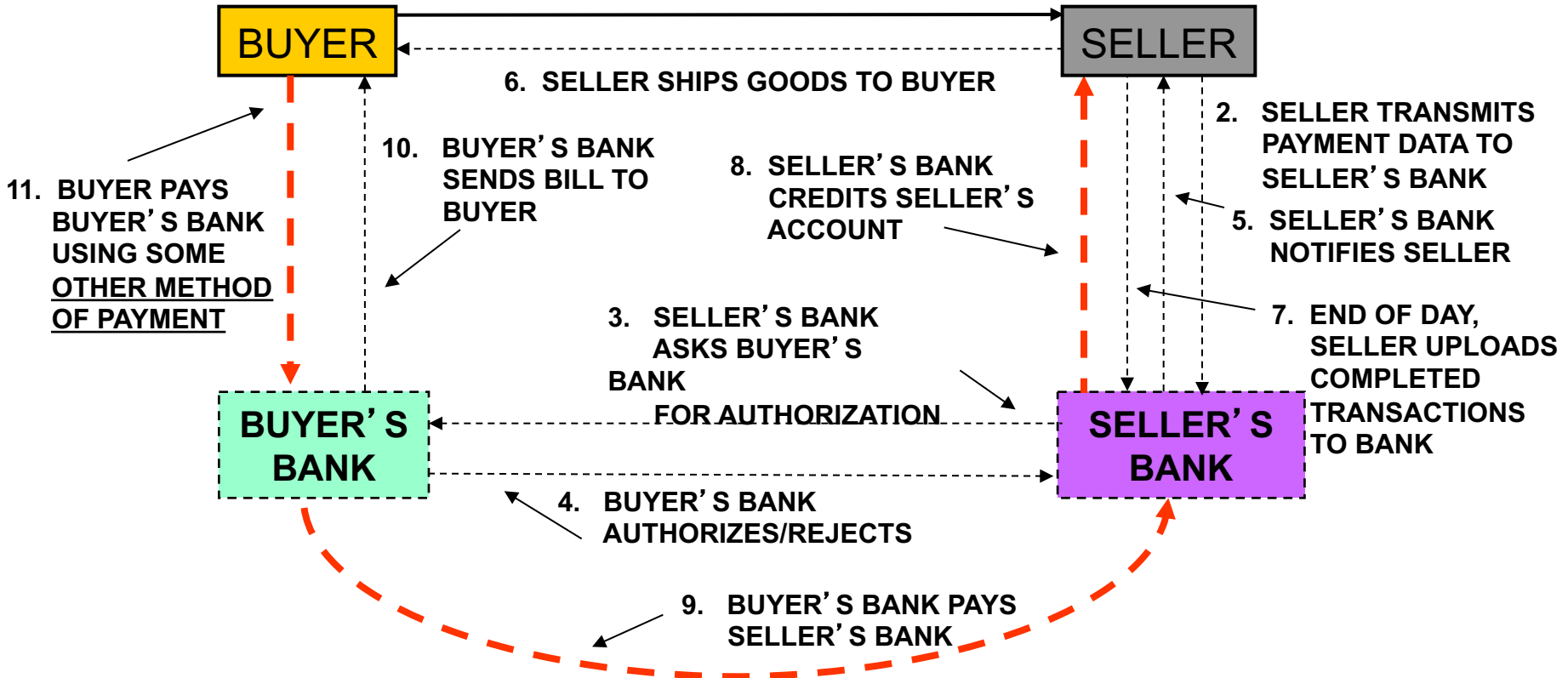
# Objective of Payment Systems

- To allow the payee to obtain money, fiduciary or its equivalent
  - ◆ Usually in his/her bank account (convertible to fiduciary)
  - ◆ Cash is rare except for low-value face-to-face payments
  - ◆ How does the money get into the bank account?
- Payment in real money is called settlement
- Most payments are not settled individually
  - ◆ Example: bank checks, ATM withdrawals – too small for separate transfers of funds; batched for efficiency
- Batching to determine how much money must be paid is called clearance or clearing
- Payment systems must provide for both clearance and settlement



# Credit Card Transaction

1. BUYER TENDERS CREDIT CARD INFO TO SELLER



**CLEARANCES:**

- 2. HOW MUCH SHOULD SELLER GET?
- HOW MUCH SHOULD EACH BANK GET/PAY?
- 10. HOW MUCH SHOULD BUYER'S BILL BE?

**HOW?  
HOW MUCH?**

**SETTLEMENTS:**

- 7. SELLER GETS PAID
- 9. SELLER'S BANK GETS PAID
- 11. BUYER'S BANK GETS PAID

# Payment Issues

- How does the payer know how much to pay?  
(bill presentment, invoicing)
- What mechanism will be used to “pay” (payment)?
- When will payment be made (before, during, after)
- How will the payments be added up? (clearance)?
- How will the payee receive real money (settlement)?
- How will the payee credit the payer (reconciliation)?
- What records are available to the parties (audit)?
- Security for all the above
  - ◆ authentication of parties
  - ◆ prevention of forgery

# Payment Systems by Timing

- Prepaid Systems (Bank access before transaction)
  - ◆ Cash
  - ◆ Octopus, phone card
  - ◆ Bank stored-value cards (GeldKarte)
- Instant-Paid Systems (Access during transaction)
  - ◆ Debit card
- Post-Paid Systems (Access after transaction = credit)
  - ◆ Credit card, EZPass, Speedpass
  - ◆ Checks & electronic forms, eChecks
  - ◆ Commercial invoice
- Huge differences in risk, authentication, cost

# Some “Payment” Methods

- Cash
- Check/ Cheque
- Travellers Check
- Point-of-sale debit
- ATM
- Credit transfer (giro), Automated Clearing-House (ACH)
- Interbank transfer (FPS, EFT – electronic funds transfer)
- Credit cards
- Payment cards, smart cards (Octopus, Mondex)
- Loyalty Systems (Frequent Flyer Mileage programs)
- Intermediates, P2P systems: Paypal, Venmo, Payme, O!ePay
  - ◆ Mobile Payment Services, e.g. Alipay, WeChat Pay, Paybox
- Electronic Cash (by David Chaum of DigiCash), still issued by a bank
- Crypto-currencies: Bitcoin, Ethereum.

# System Issues

- Physical support (smart card, files, encrypted strings)
- Value representation (denominations, numbers)
- Location of value store (bank, electronic wallet)
- Discharging power (who accepts it?)
- Mode of use (remote, face-to-face)
- Methods of payment (credit transfer, jeton exchange)
- Genuineness (is it valid? stolen? double-spent?)
- Authentication (of user)
- Traceability (anonymity, privacy)
- Scalability, cost

# Desired Properties of Money

- Universal acceptance
- Transferability, portability
- Safety (unforgeable, unstealable)
- Privacy (no one except parties know the amount)
- Anonymity (no one can identify the payor)
- Work off-line (no need for on-line verification)
- Divisible into change (pay for \$10 item with \$100 bill)
- Arbitrary denominations (e.g. \$325.14)

# Costs of Money

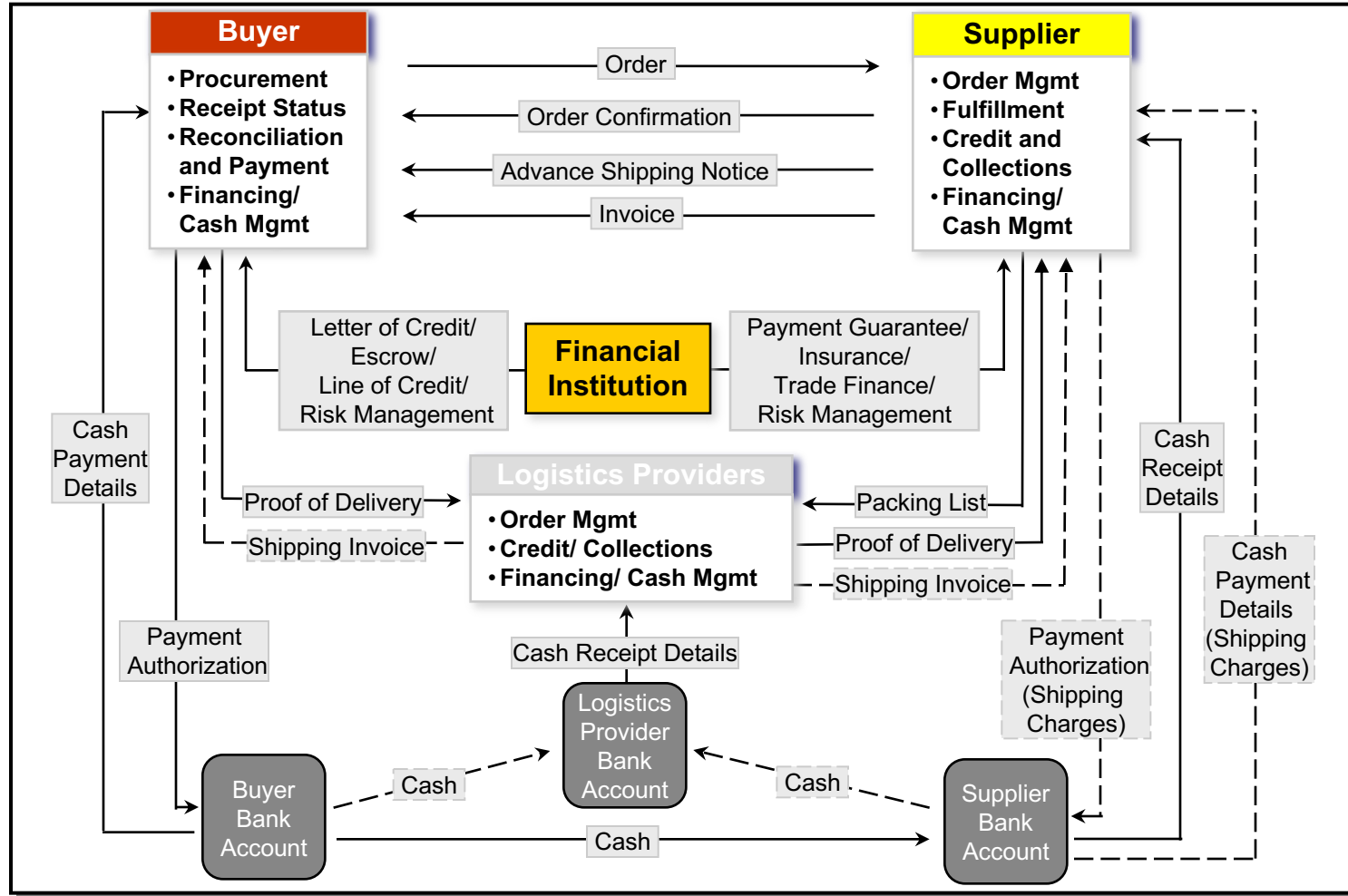
- Time
- Risk
- Physical cost (print currency, mint coins)
- System infrastructure
- Processing cost (transactions)
- Security
- Human time
- Law enforcement



# B2B Payments

- High dollar value
- Tied to paperwork
  - ◆ Requisitions, authorization, purchase order, shipping documents
- Financial controls, auditing
- Connection with legacy ERP and accounting systems
- Cash management
- International issues
  - ◆ Customs documents, foreign currency

# B2B Payments

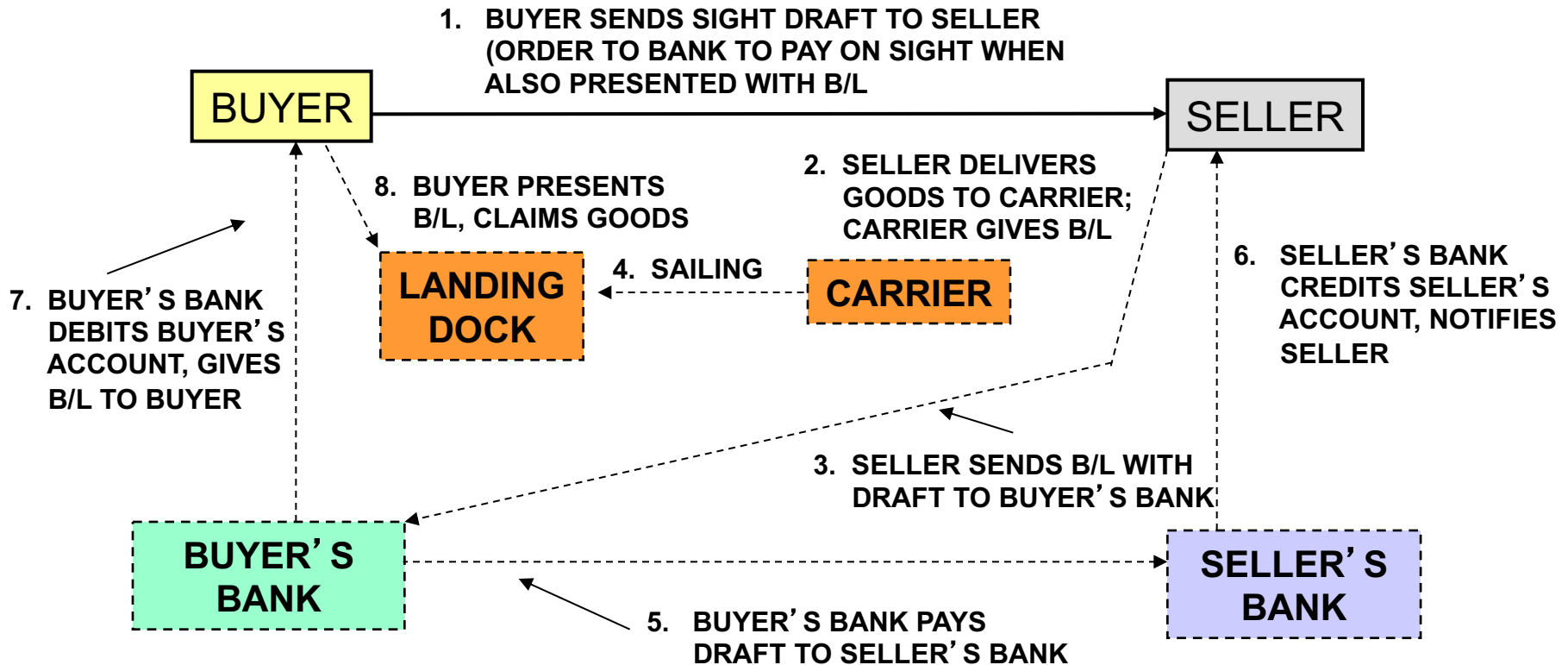


**Goods Move Faster Than Money**

SOURCE: [TRADECARD](#)

# Bill of Lading (B/L) Transaction

PURPOSE: LINK PAYMENT TO SHIPMENT



CARRIER IS AN ESCROW AGENT. IF B/L IS NOT PRESENTED, GOODS WILL NOT BE DELIVERED. IF SELLER NEVER SHIPS GOODS, THERE WILL BE NO B/L AND BUYER'S BANK WILL NOT PAY

# Additional Considerations

# Payment Risks

- ALL RISK HAS COST
  - ◆ Suffering loss has cost
  - ◆ Protecting against loss has cost
- System design must respond to risk posture (willingness to accept various kinds of risk)
- Transferable v. non-transferable risk
  - ◆ Insurance
  - ◆ Hedging
- Example tradeoff: open v. closed payment networks

# Payment Risks

System design must respond to risk posture

- Operational (reliability and integrity)
  - ◆ Security (unauthorized access)
  - ◆ Employee fraud
  - ◆ Counterfeiting (ecash)
  - ◆ System design, implementation, maintenance
  - ◆ Customer misuse
  - ◆ Service provider risk
  - ◆ System obsolescence
  - ◆ Transaction repudiation by customer

# Payment Risks

## ■ Reputational

- ◆ Negative public opinion ?==? loss of business
  - ✦ Bank of New York Russian money laundering
  - ✦ Lose both legitimate customers AND launderers
- ◆ System deficiencies
- ◆ Security breach
- ◆ Failure of similar systems

## ■ Systemic

- ◆ Risk that failure to meet an obligation spreads through the system, causing others to fail to meet obligations



# Payment Risks

## ■ Legal

- ◆ Violation of law, ambiguity, legal sanctions
- ◆ Money laundering
- ◆ Inadequate disclosure
- ◆ Violation of privacy
- ◆ Violation by linked site
- ◆ Certificate authority risk
- ◆ Foreign law

# Payment Risks

## ■ Banking

- ◆ Credit (non-payment, insolvency)
- ◆ Liquidity (demand for redemption of ecash)
- ◆ Interest rate (spread)
- ◆ Market (inflation, foreign exchange)
- ◆ Cross-border (social, political, economic)

## ■ Crime

- ◆ Fraud, forgery
- ◆ Theft
- ◆ Kiting (illegal use of float)

# Summary of Major Ideas

- Money classifications
  - ◆ Token v. notational (what form does it take?)
  - ◆ Fiduciary v. scriptural (government or issuer-based)
  - ◆ Prepaid, Instant-Paid, Postpaid
- Payment methods
- Cash is very expensive to use
- B2B payments are complex
- Atomicity between shipments and payments is difficult to achieve