

CloudEx: A Financial Application in the Cloud

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Accurate Timing is Foundational for the Financial Industry

Exchanges and Trading Platforms

(**Conventional exchanges:** Nasdaq, NYSE, SGX, LSE, TSE, HKSE, Euronext, Chicago ME)
(**Digital currency exchanges:** Coinbase, Binance, GDAX)

- Ensure “fairness”: in-order execution of transactions
- Enable execution of “time-synced smart contracts”
- Make hybrid and cloud-only models possible

Investment Banks and Hedge Funds

(e.g., BofA, Citi, Goldman Sachs, JPMC, Morgan Stanley, UBS, Wells Fargo)

- Sync with exchanges as reference for market data timestamps
- Run realistic simulations for better trading algorithms
- Regulatory compliance: MIFiD II in the EU and CAT in the US

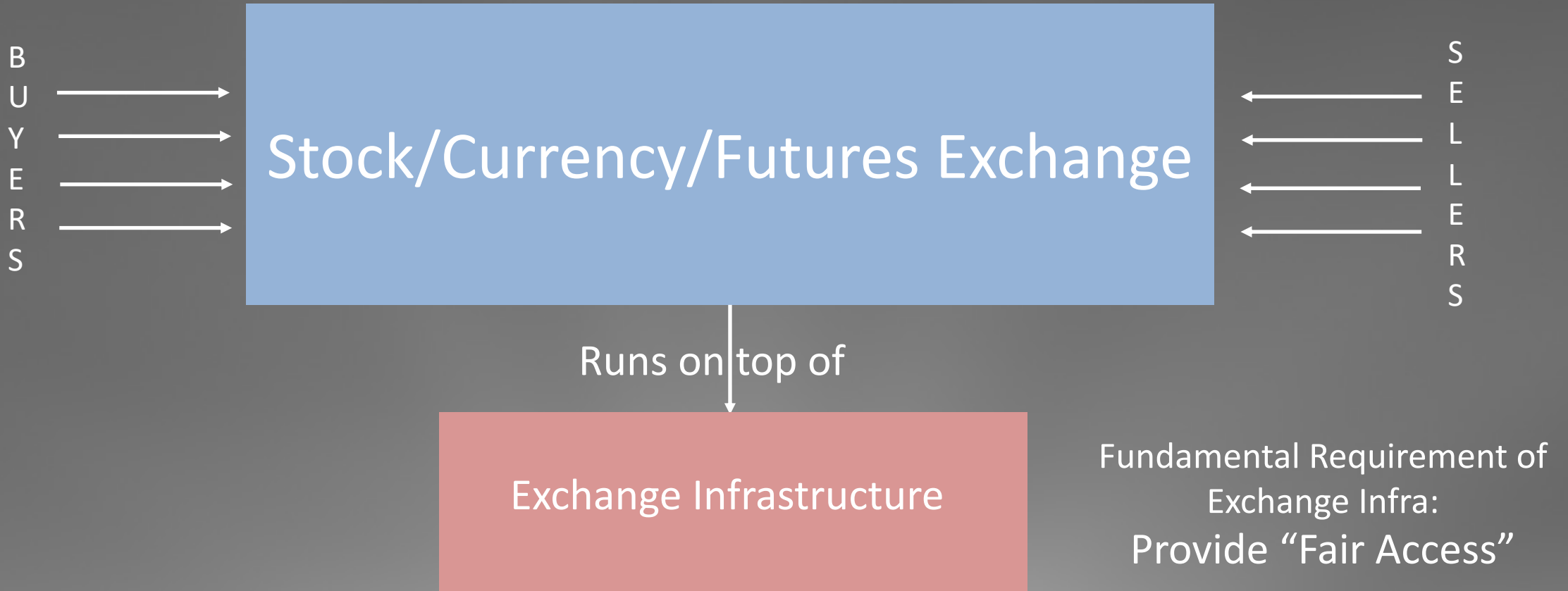
Payments and Retail Banking

(e.g., Visa, Mastercard, Paypal, eBay, Wells Fargo, HSBC, Sumitomo, Barclays)

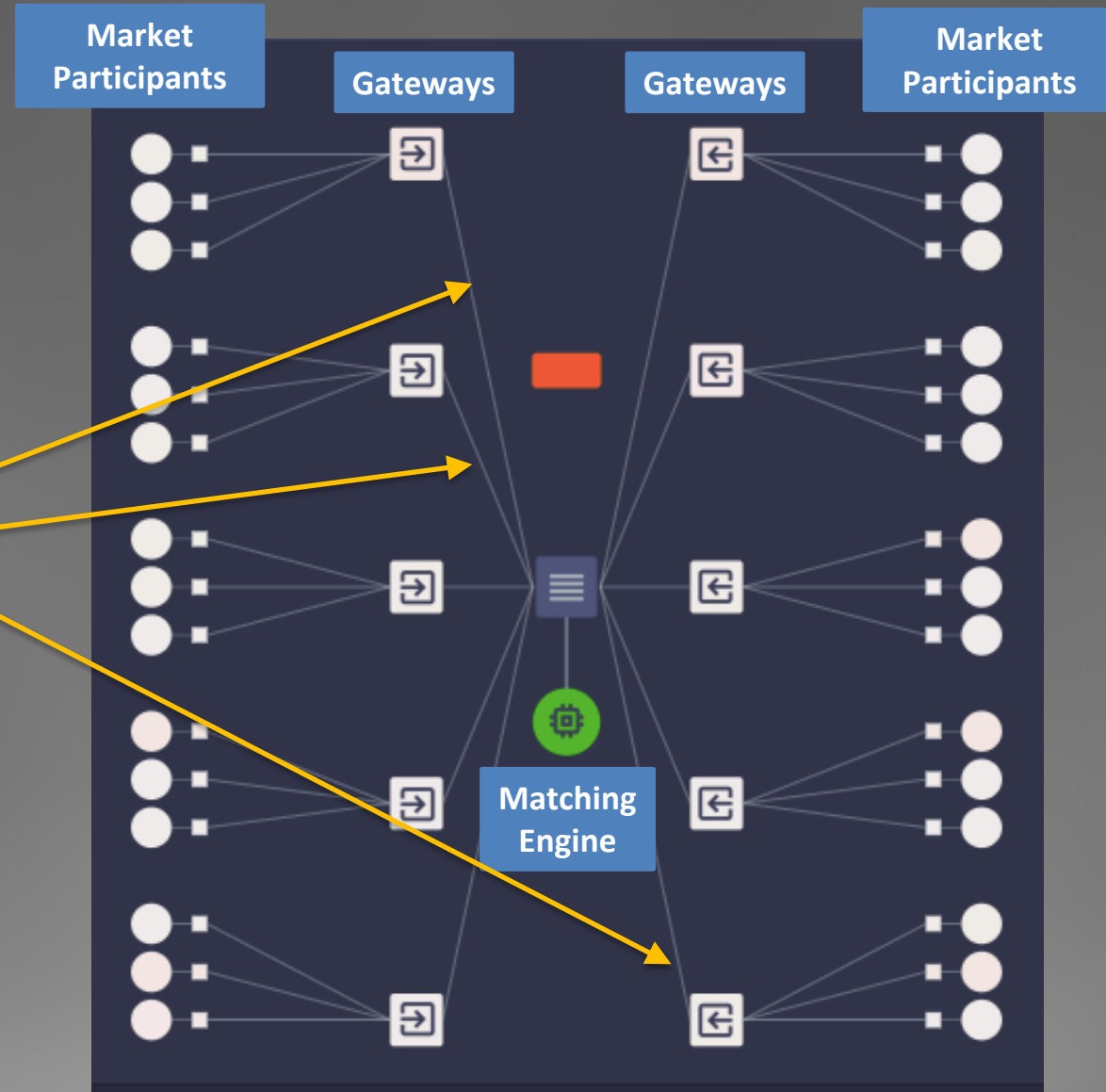
- Accurately timestamp transactions across disparate geographies for transaction tracking/debugging
- Recreate network dynamics for 100s of apps

Financial Trading Systems

Fundamental Operation Performed by Exchange:
Price Discovery!



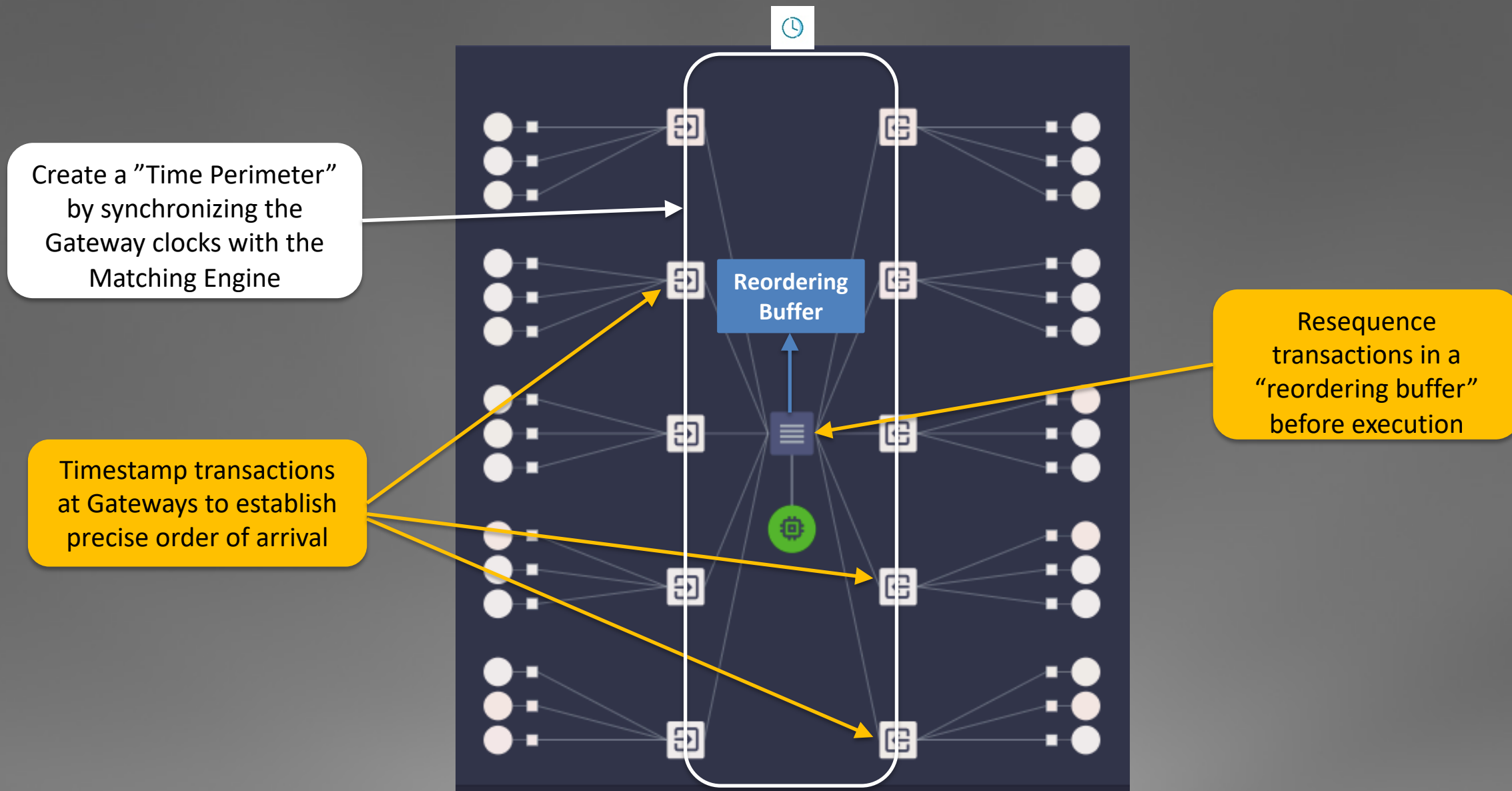
Fairness #1: In-order Execution of Transactions



In on-prem exchanges, links from Gateways to Matching Engine carefully engineered to ensure equal transit times

This is not possible in the Cloud; hence more challenging

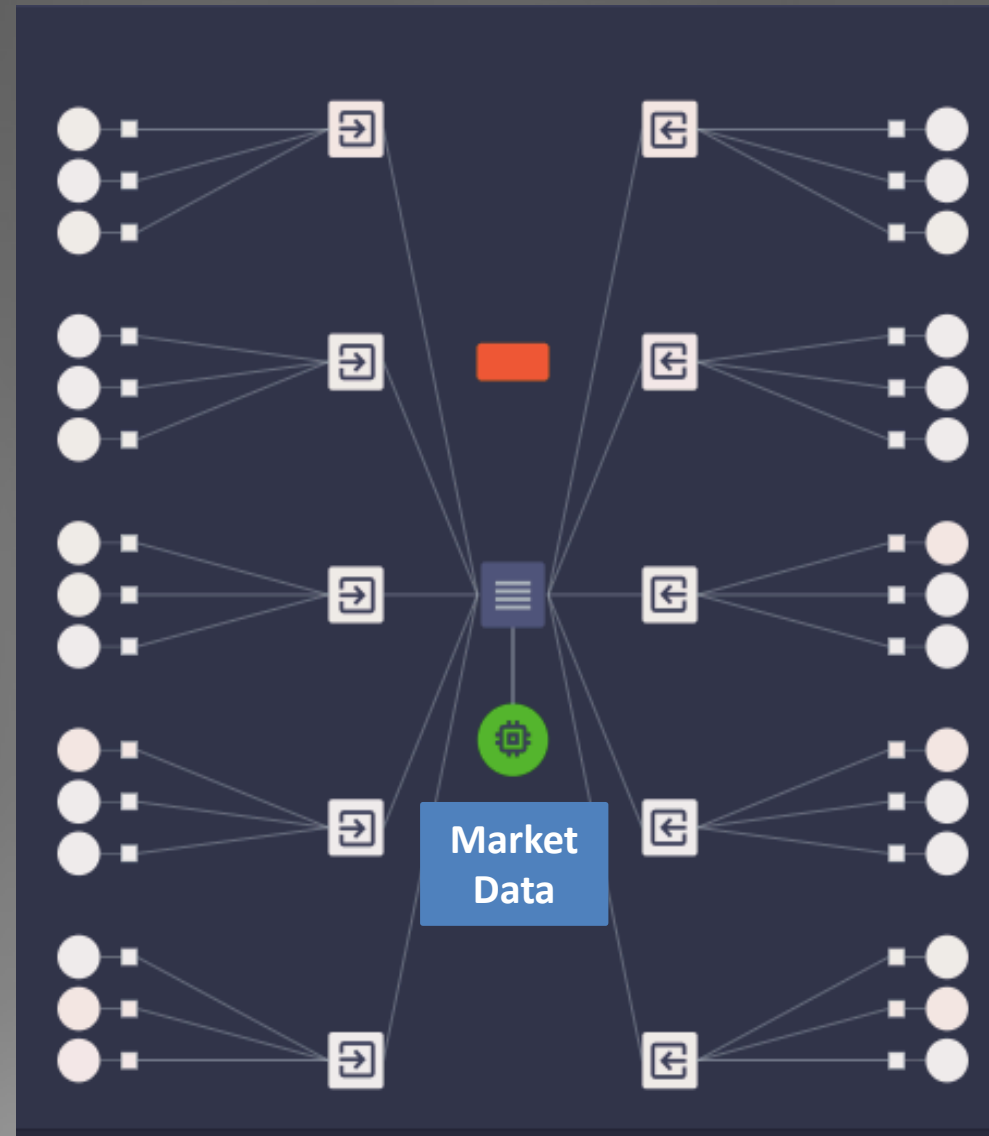
Solution: Create "Time Perimeter" Using Accurate Clock Sync



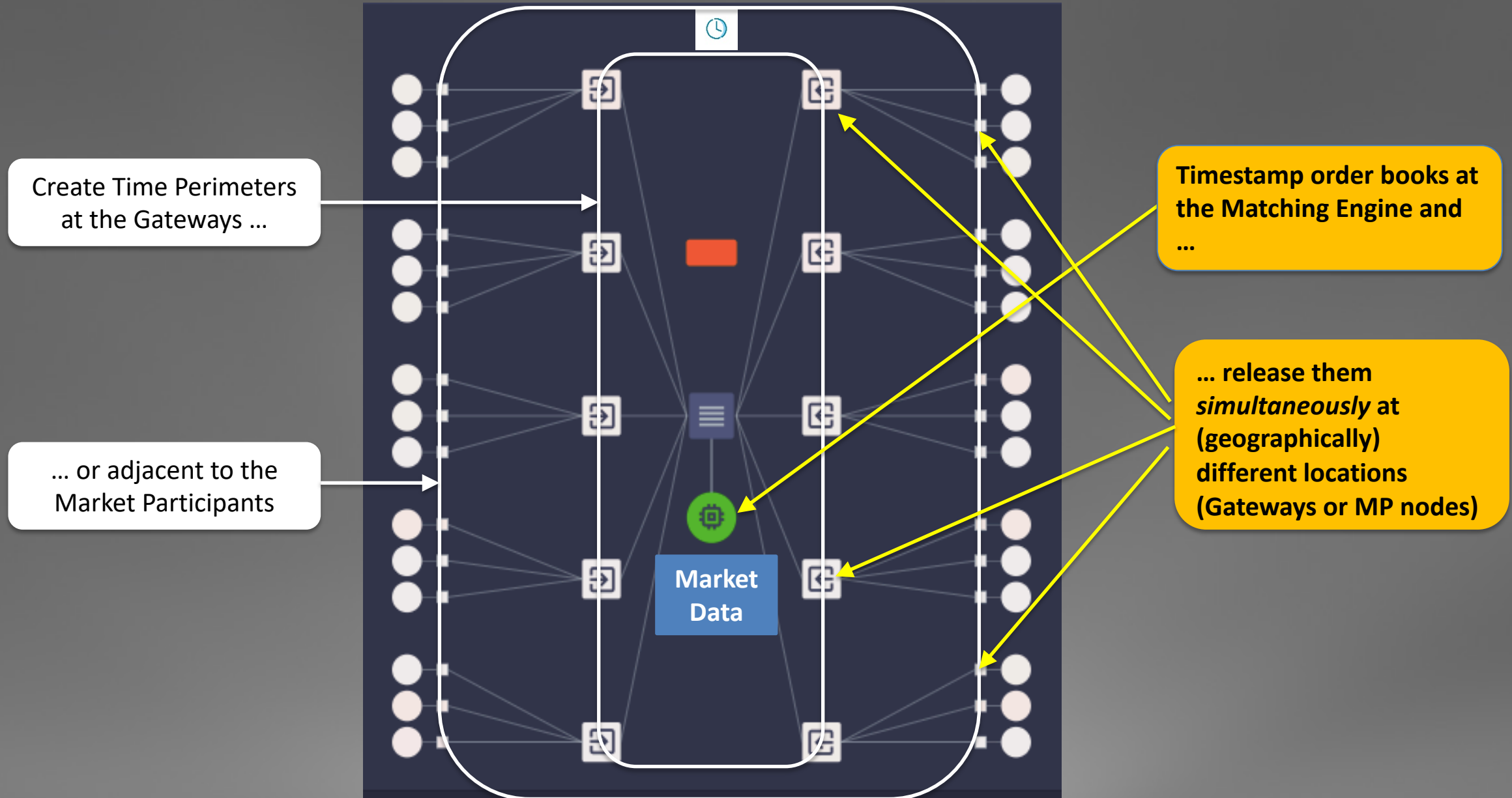
Fairness #2: Delivering Market Data Simultaneously

Market data is currently delivered simultaneously to participants by multicasting

Multicasting is not easy in the Cloud



Solution: Time Perimeters + Hold-and-Release Buffers

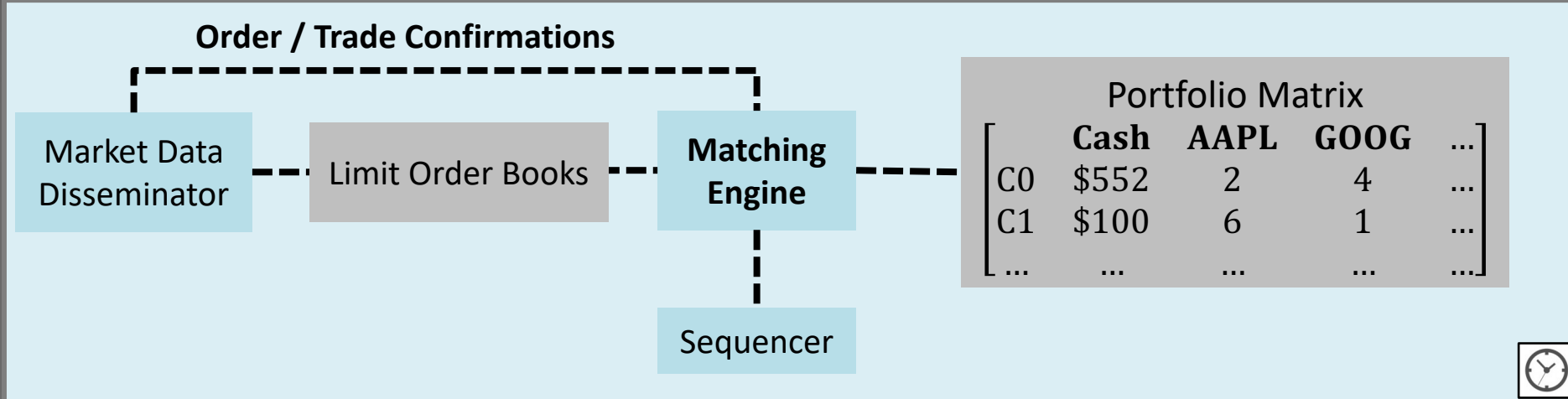


Motivation for CloudEx

- Carefully-engineered networks are expensive to scale and maintain
 - Cloud-based solutions are elastic and typically easier to maintain
- Research tool
 - Fully configurable end-to-end exchange
- Teaching tool
 - Prototype system for learning about (i) infrastructure, (ii) trading algorithms, and (iii) matching algorithms

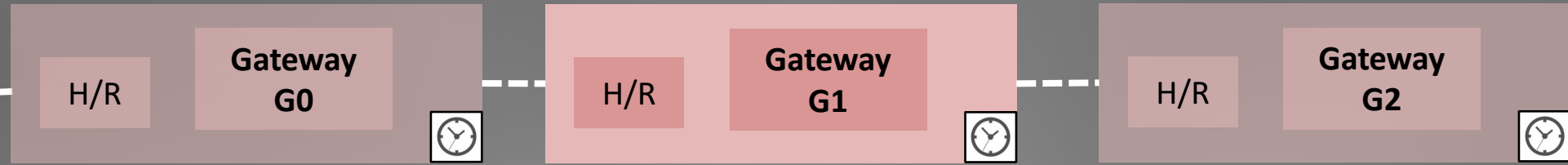
System Design of CloudEx

BigTable
Storage



Time Perimeter

Time Perimeter



Trader
C0

Trader
C1

Trader
C2

Order Messages

Appended by Gateway

Format

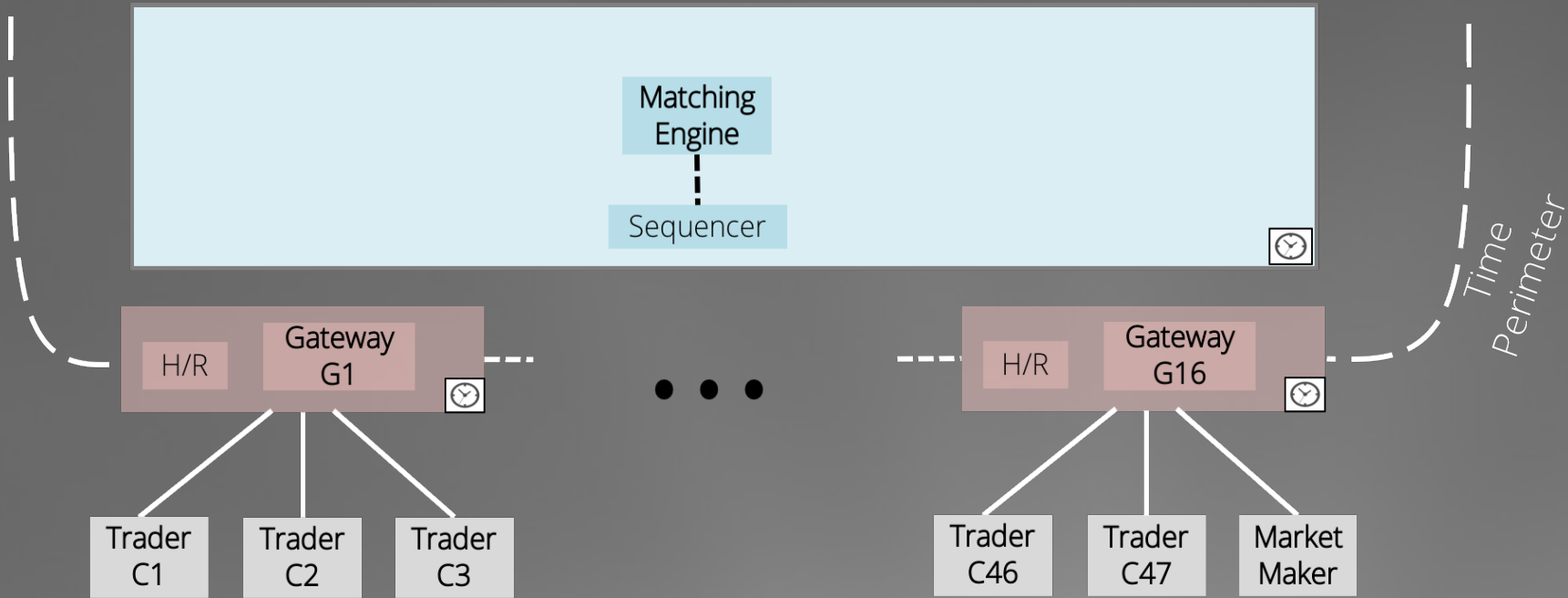
Symbol	Action	Shares	Type	Bid/Ask Price	Timestamp	Client ID	Order ID
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Examples

AAPL	Buy	100	Limit	\$210	1569290045000	C1	SAD651GH
GOOG	Buy	50	Market	\$1200	1569290048121	A2	3AS5SDF2
MSFT	Sell	325	Limit	\$140	1569290053007	B2	A22S134H

CloudEx Trading Strategies and Demo

Demo Setup



- 1 Matching Engine
- 48 Traders, 3 per Gateway
- 10 symbols to trade
- Each trader start with 20M cash and 10k shares per symbol

Traders

1 Market Maker

Trader
C48

- Has large resources that allows it to transact in big volumes and drive the price of a symbol towards some predetermined price

43 Random Traders

Trader
C21

- Models traders that perform trades without reacting to instantaneous market data

4 Algorithmic Traders

Trader
C1

- Uses a **mean reversion strategy** to profit on volatility in certain symbols
- *Underlying assumption:*
 - *Stock prices follow Brownian Motion (random walk) with a tendency to revert to their mean.*

Mean Reversion Strategy

Algorithm Data

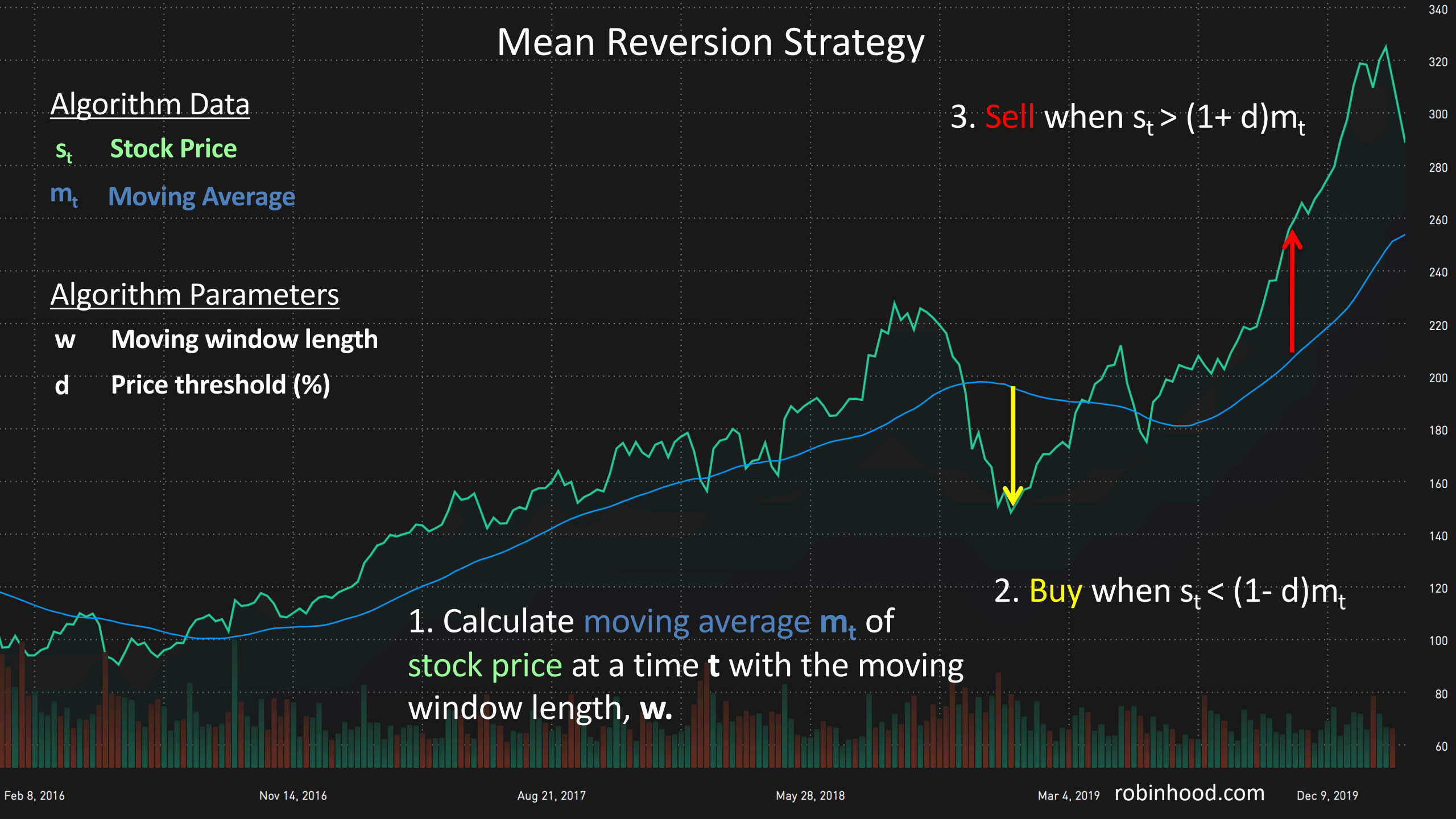
s_t Stock Price

m_t Moving Average

Algorithm Parameters

w Moving window length

d Price threshold (%)



1. Calculate moving average m_t of stock price at a time t with the moving window length, w .

3. Sell when $s_t > (1+d)m_t$

2. Buy when $s_t < (1-d)m_t$

Demo