FNA

Using Network Simulations to Design FMIs

What are Simulations

Methodology to understand complex systems – systems that are large with many interacting elements and or non-linearities (such as payment systems)

In contrast to traditional statistical models, which attempt to find analytical solutions

Usually a special purpose computer program is used that takes granular inputs, applies the simulation rules and generates outputs

Take into account second rounds effects, third round, …

Inputs can be stochastic or deterministic. Behavior can be static, pre-programmed, evolving or co-learning

Short History of FMI Simulations

1997 : Bank of Finland

Evaluate liquidity needs of banks when Finland's RTGS system was joined with TARGET

2000 : Bank of Japan and FRBNY

Test LSM features for BoJ-Net/Fedwire

2001 - : CLS approval process and ongoing oversight

Test CLS risk management

Evaluate settlement' members capacity for pay-ins

Understand how the system works

Since: Bank of Canada, Banque de France, Nederlandsche Bank, Norges Bank, TARGET2, and many others

2010 - : Bank of England, CHAPS

Evaluate alternative liquidity saving mechanisms

Use as platform for discussions with banks

Agent Based Modeling

Analytical models need to make many simplifying assumptions.

Problem with static simulations based on historical records is that behavior of banks is not taken into account.

This behavior may have material impact on results in most simulation questions, eg:

- When system features are changed
- In stress situations
- As a reaction to other behavioral changes

-> Agent Based Modeling

Agent Based Models

Each agent has a set of rules that define its behavior
-> system level emergent behavior

Choices

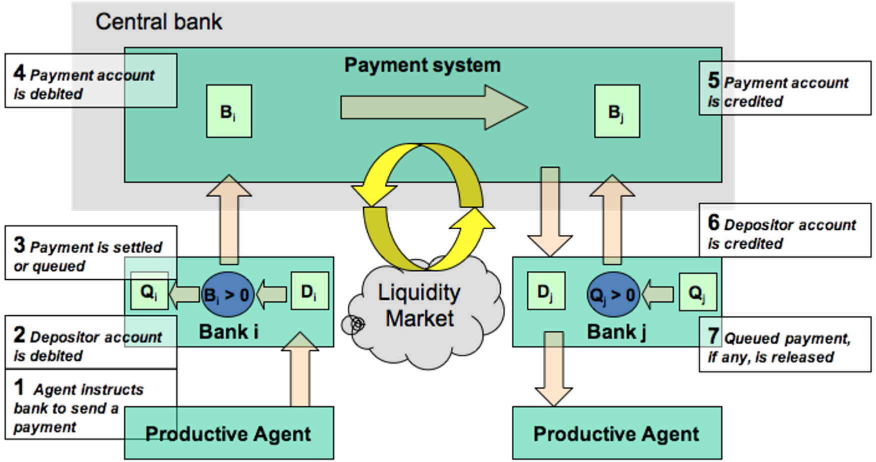
- design of rules
- homogeneous vs heterogeneous agents
- static vs learning agents

Pros

- ability to model complex behaviors
- flexible and realistic
- real systems are sensitive to details of implementation

Cons

- time consuming to set up
- need many input parameters
- results very sensitive to modeling assumptions



Beyeler, Glass, Bech and Soramäki (2007), Physica A, 384-2, pp 693-718.

Agent Based Models

Existing literature

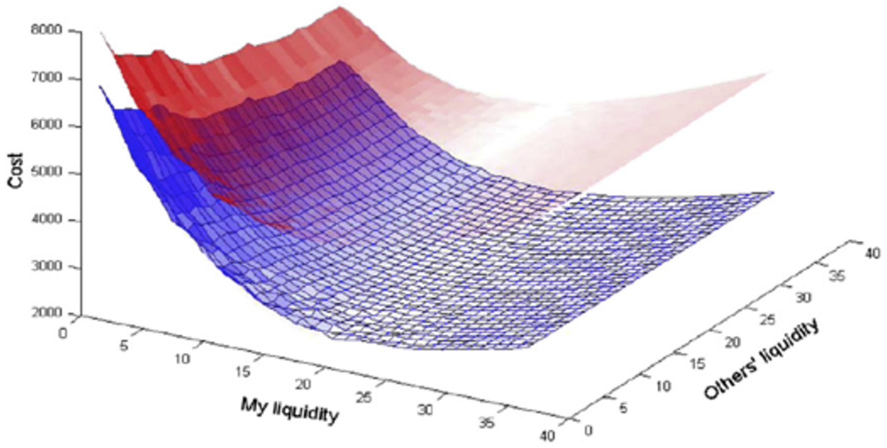
- Galbiati and Soramäki (2008, 2010)
- Arciero et al (2009)
- McLafferty-Denbee (2013)
- Soramäki and Cook (2015)

Results

- Behavior has material impact on results
- Behavior increases delays (or moves away from social liquidity/delay optimum)

Questions

- Money market model
- One vs multiperiod, learning vs fixed populations
- Which payments are discretionary / known
- What is the cost of liquidity/delay tradeoff
- Human vs machine behavior



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Data Needs

Data Needs

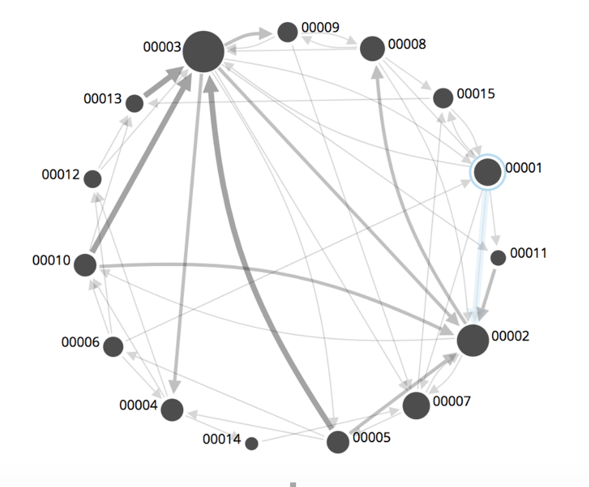
Historical transaction data

- From interbank payment systems
- At minimum: date, time, sender, receiver, value
- More data on type of payment, economic purpose, second tier (if any), type of institution, etc. useful

Representative transaction data

- Based on aggregates or sampling of real data
- Based on a network model (defining bilateral flows)
- Assumptions about:
  - Timing of payments
  - Value distribution
  - Correlations (eg do larger participant send larger payments)
- System stability (net flows over longer times)

FNA R&D: Generating Representative Transaction Data




```
date,time,value,sender,receiver
2017-06-03,08:03:36,5,A,B
2017-06-03,08:06:12,7,A,C
2017-06-03,09:13:35,11,D,A
2017-06-03,11:19:26,1,C,B
2017-06-03,13:25:11,4,B,D
```

FNA R&D – Generating Representative Transaction Data

Background

Real transaction data held by FMI's and Banks is highly confidential and hard to get access to. Also as historical records, it cannot be used as input data in simulations about future infrastructures that may process very different flows.

Method

FNA has developed and vetted in several client projects a method for generating representative transaction data that contains all known network and statistical properties of the real transaction data.

Outcome

The cost of simulations is lower and the speed at which projects can be completed is higher - lowering the entry barriers to start simulations. Often results with representative data prove the value of the simulations and real data can be used for sensitivity analysis.

Summary of Research ([slides])

FNA

Application Areas

FMI Simulations

1. Evaluate Changes in Environment
2. Stress Testing & Scenarios
3. Payment System Design
4. Model Validation
5. Monitoring

FNA

Framework for evaluating trade-off between liquidity and delay

Motivation

Baek, Soramäki and Yoon (2014). J. of Financial Market Infrastructures

Settlement in RTGS consumes large amounts of cash

Cash/liquidity is not free

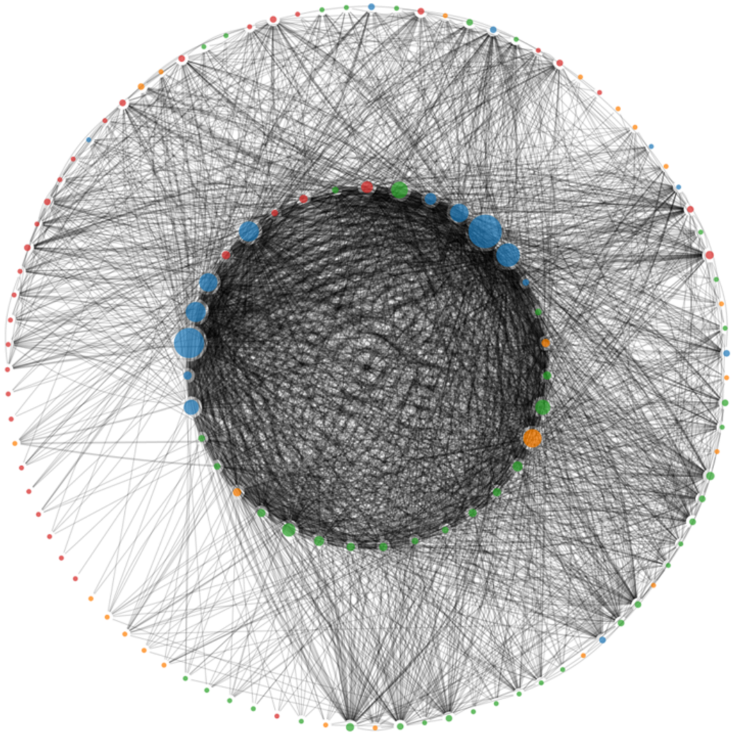
Customers' increasing demands for faster payments means delays cost too

The tradeoff is not going away even with Blockchain

There is no natural co-operative outcome

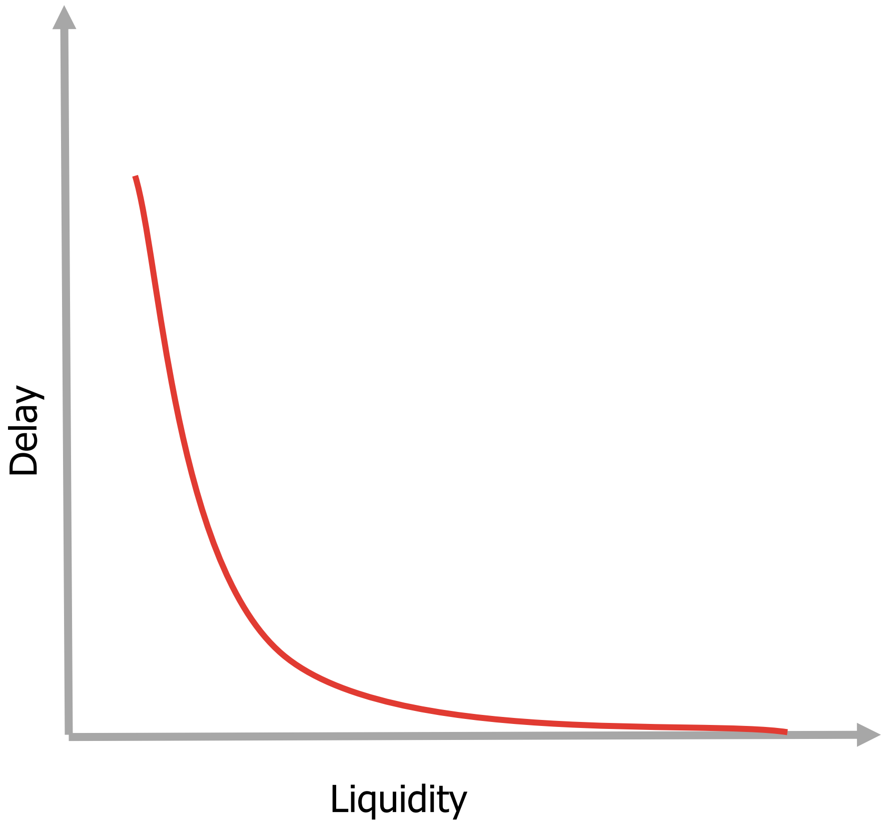
A complex system, hard to analyse

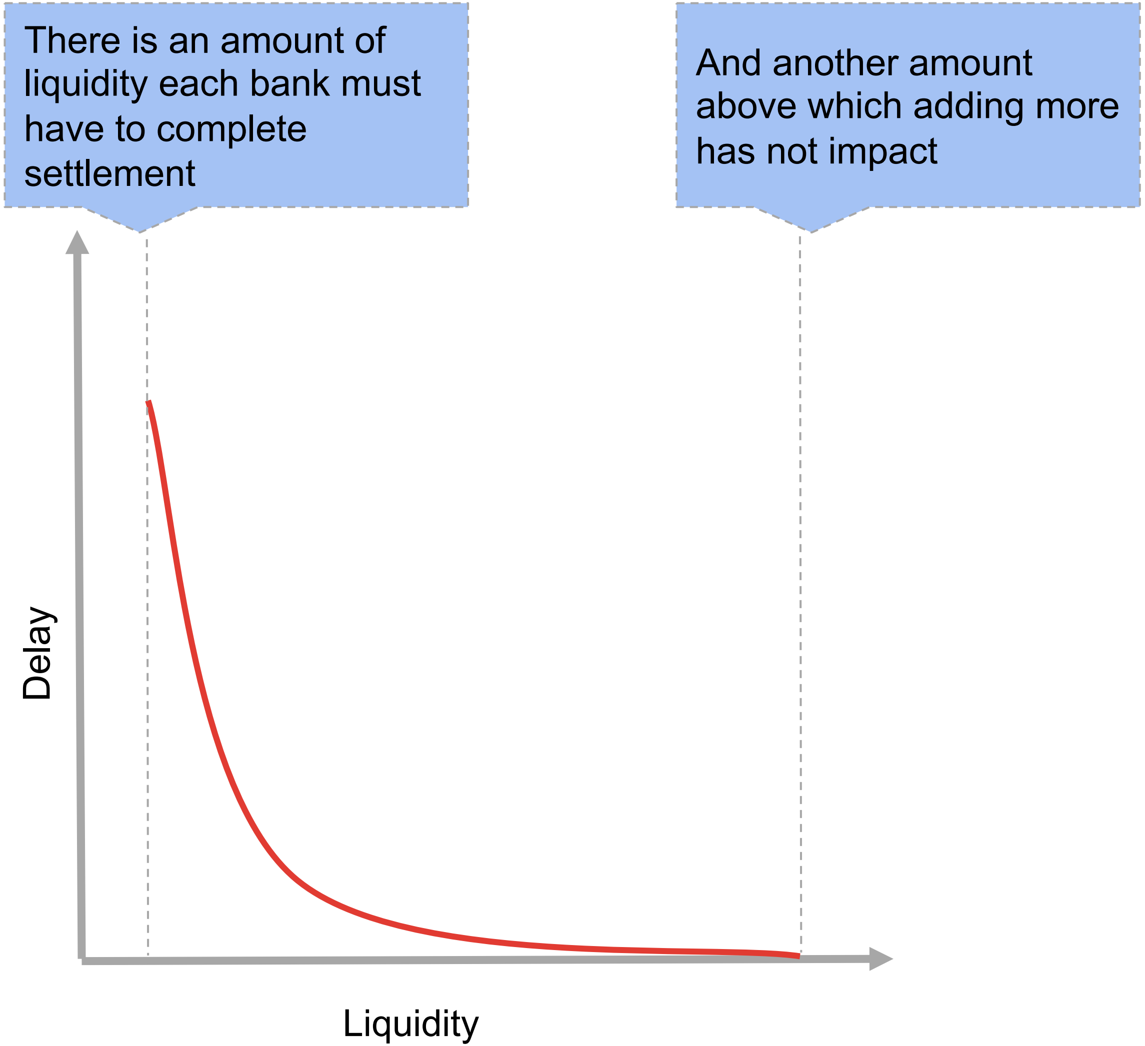
Bottom line impact

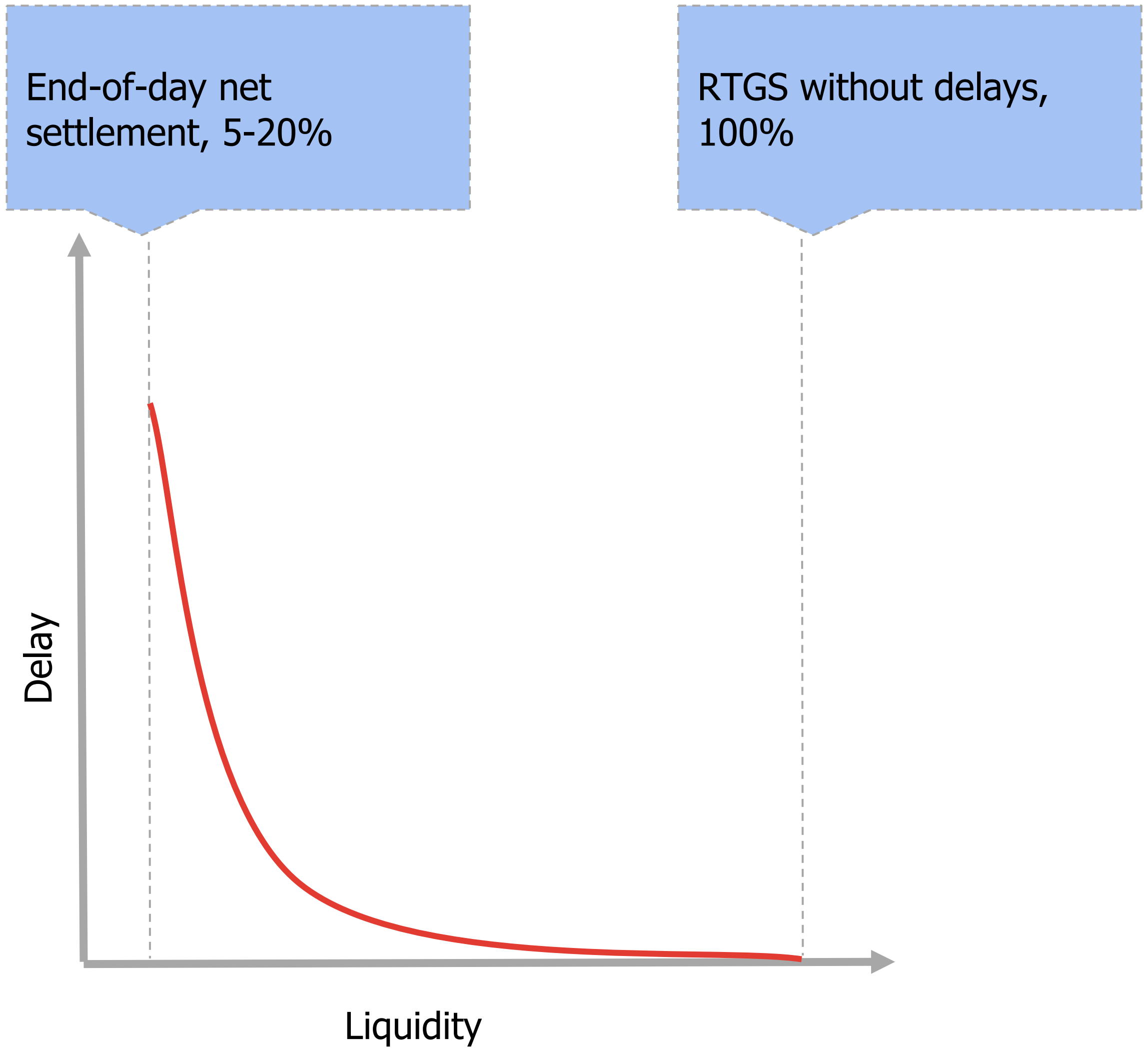


BoK-Wire+

Koponen and Soramäki (1998).
BoF monograph.

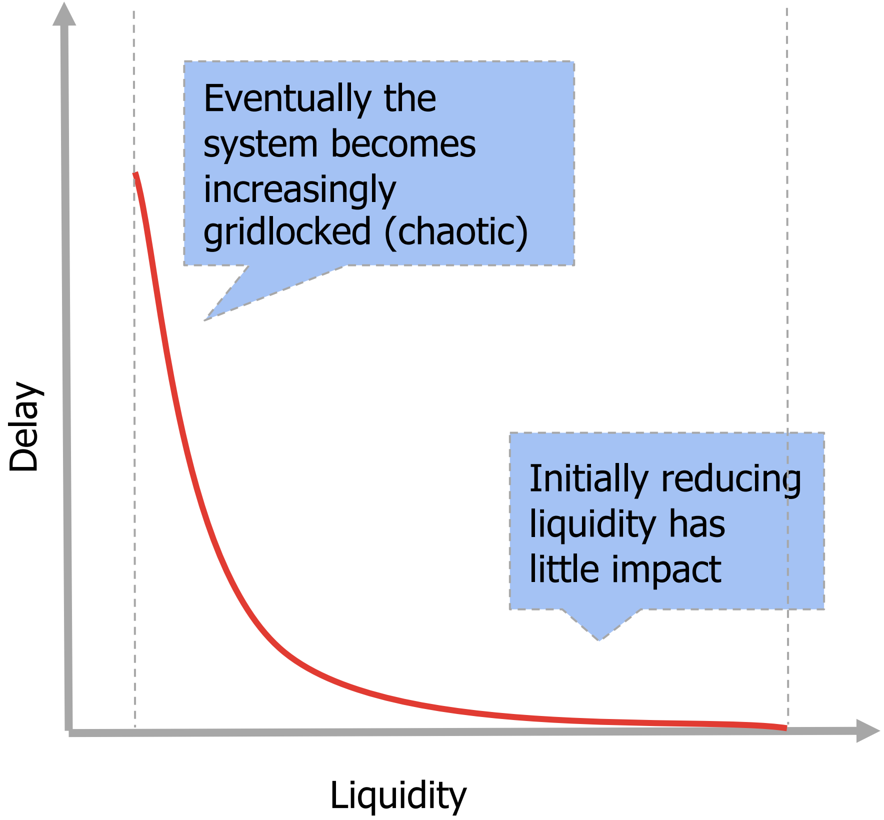



There is an amount of liquidity each bank must have to complete settlement
And another amount above which adding more has not impact
Delay
Liquidity

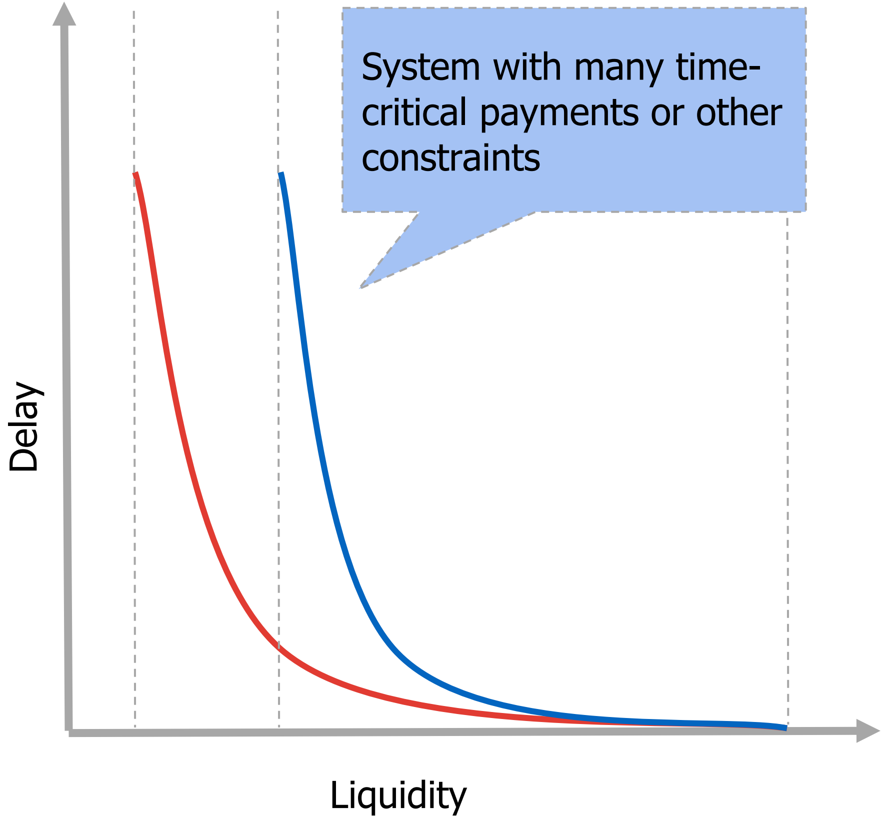

End-of-day net settlement, 5-20%
RTGS without delays, 100%
Delay
Liquidity

Bayeler, Glass, Bech, Soramäki
(2007). Physica A.

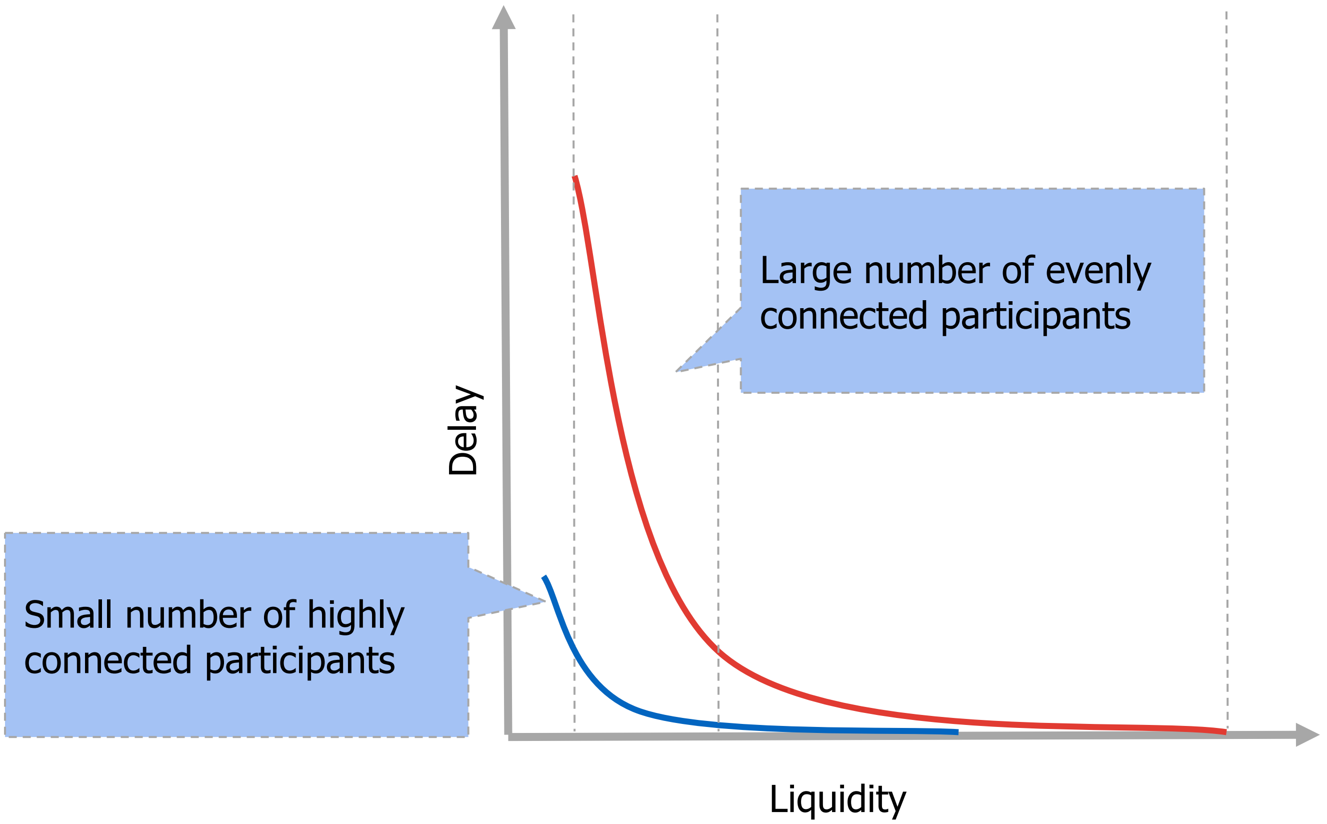
A convex shape for trade-off



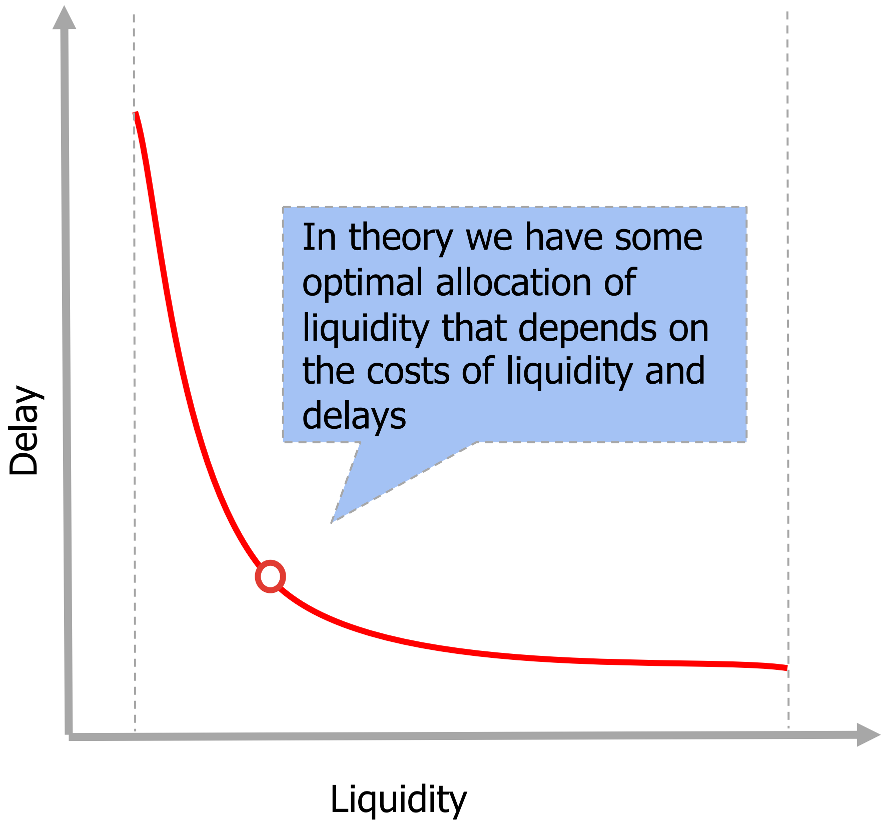
Institutional aspects matter



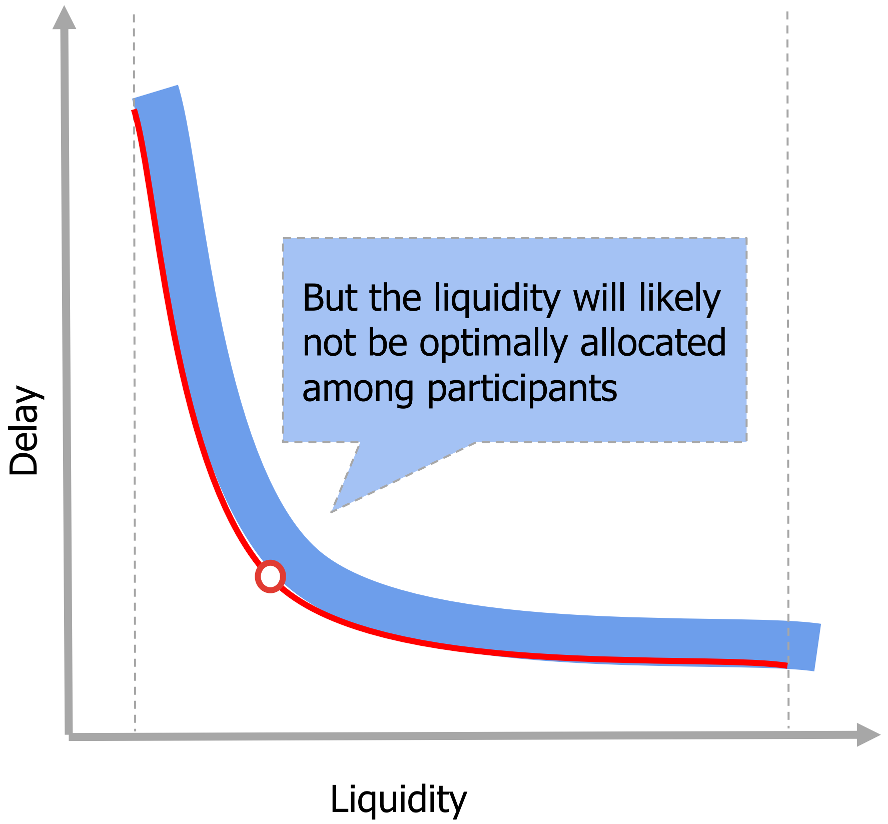
Network topology matters



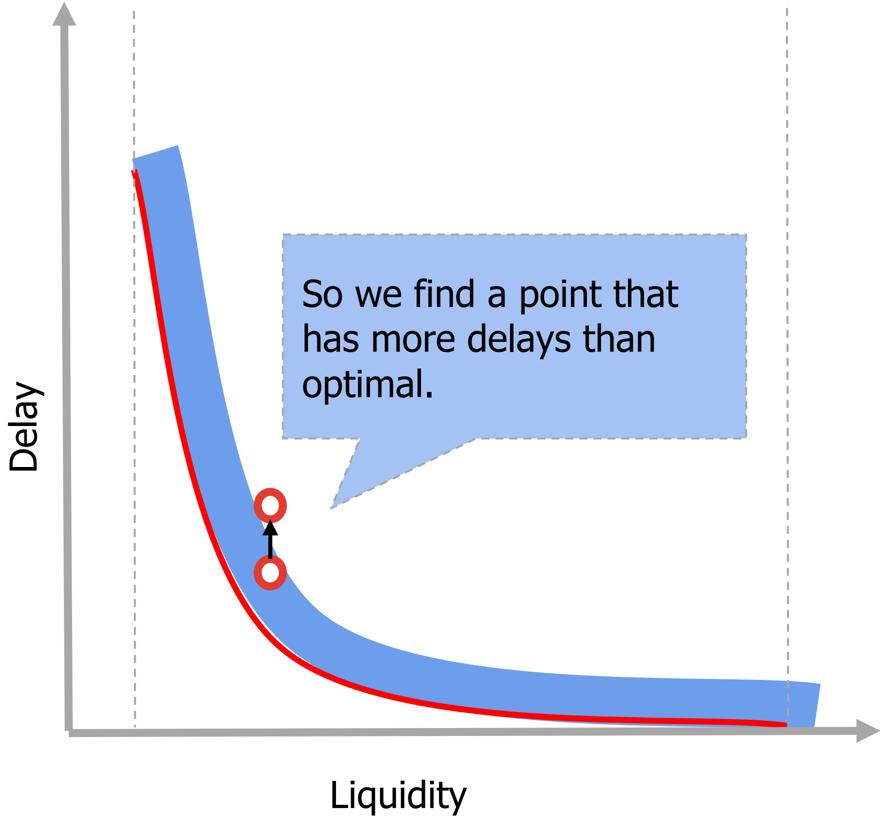
Where should we be on this curve?



Liquidity distribution matters

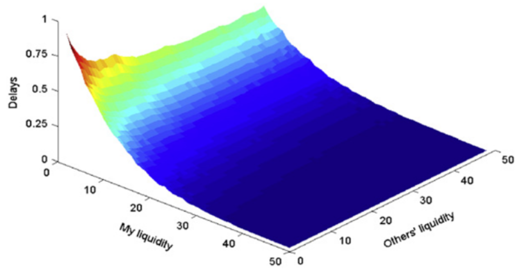


Liquidity distribution matters

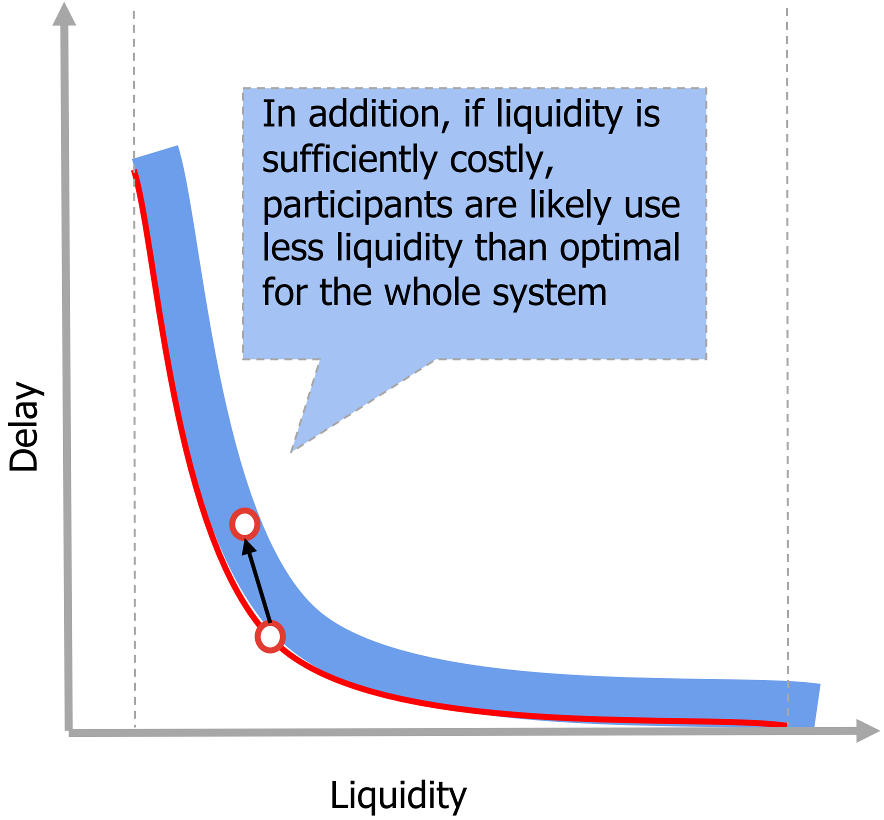


Incentives matter

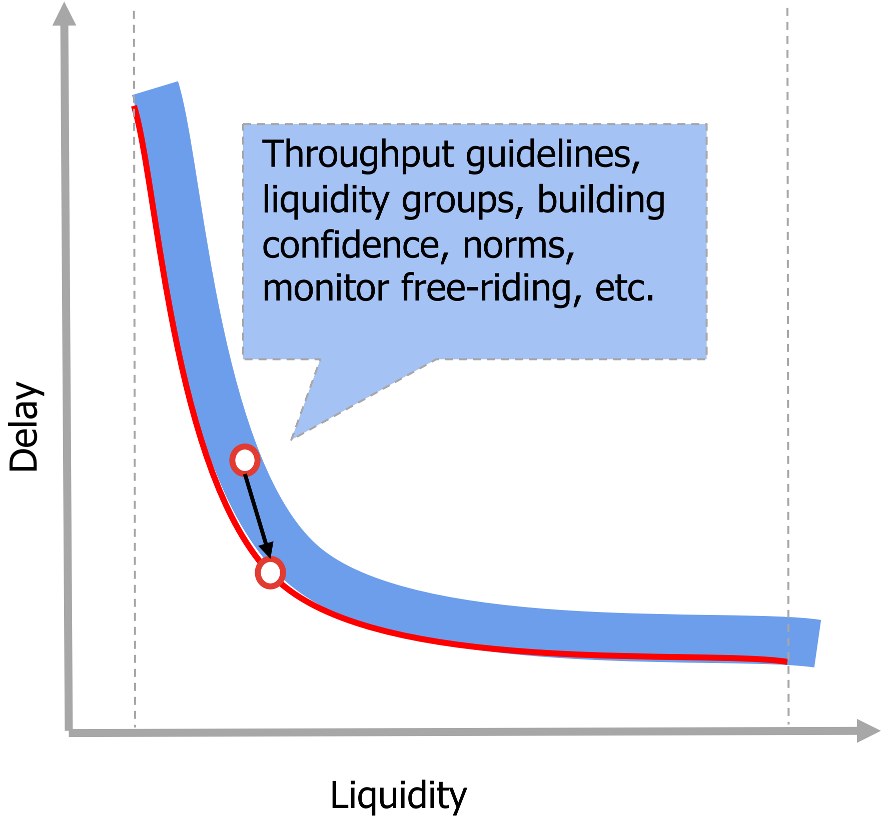
Galbiati and Soramaki (2011). J. of Econ. Dynamics and Control



Bech and Garratt (2003, 2006)

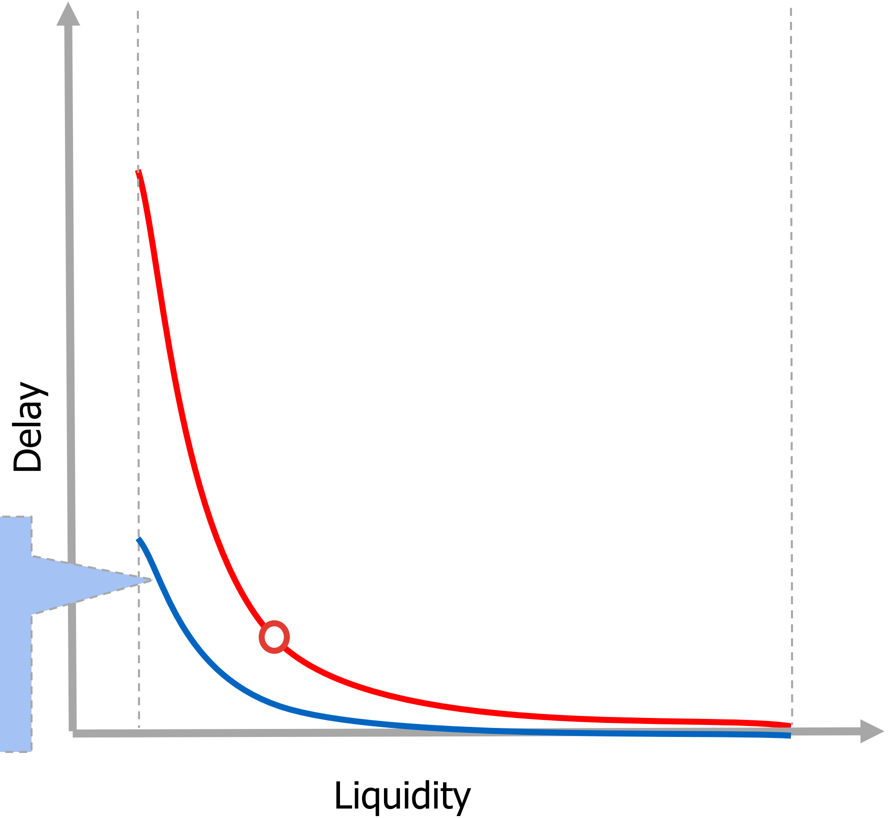


How do we foster co-operation?



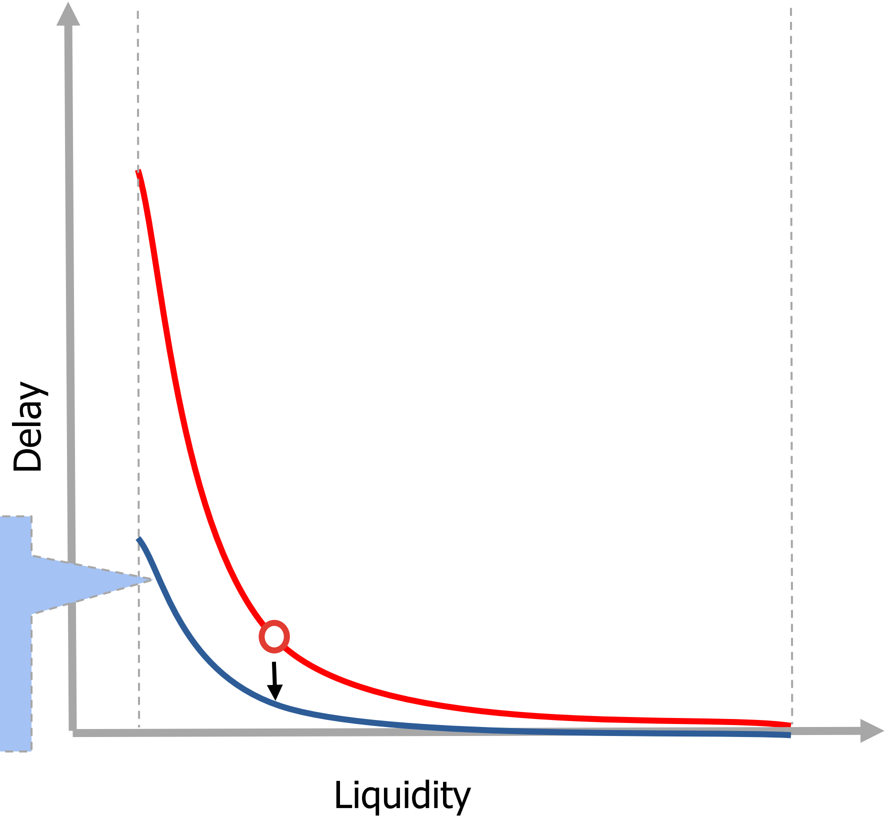
Leinonen and Soramaki (2011).
Bank of Finland WP

Liquidity Saving Mechanisms (LSMs)



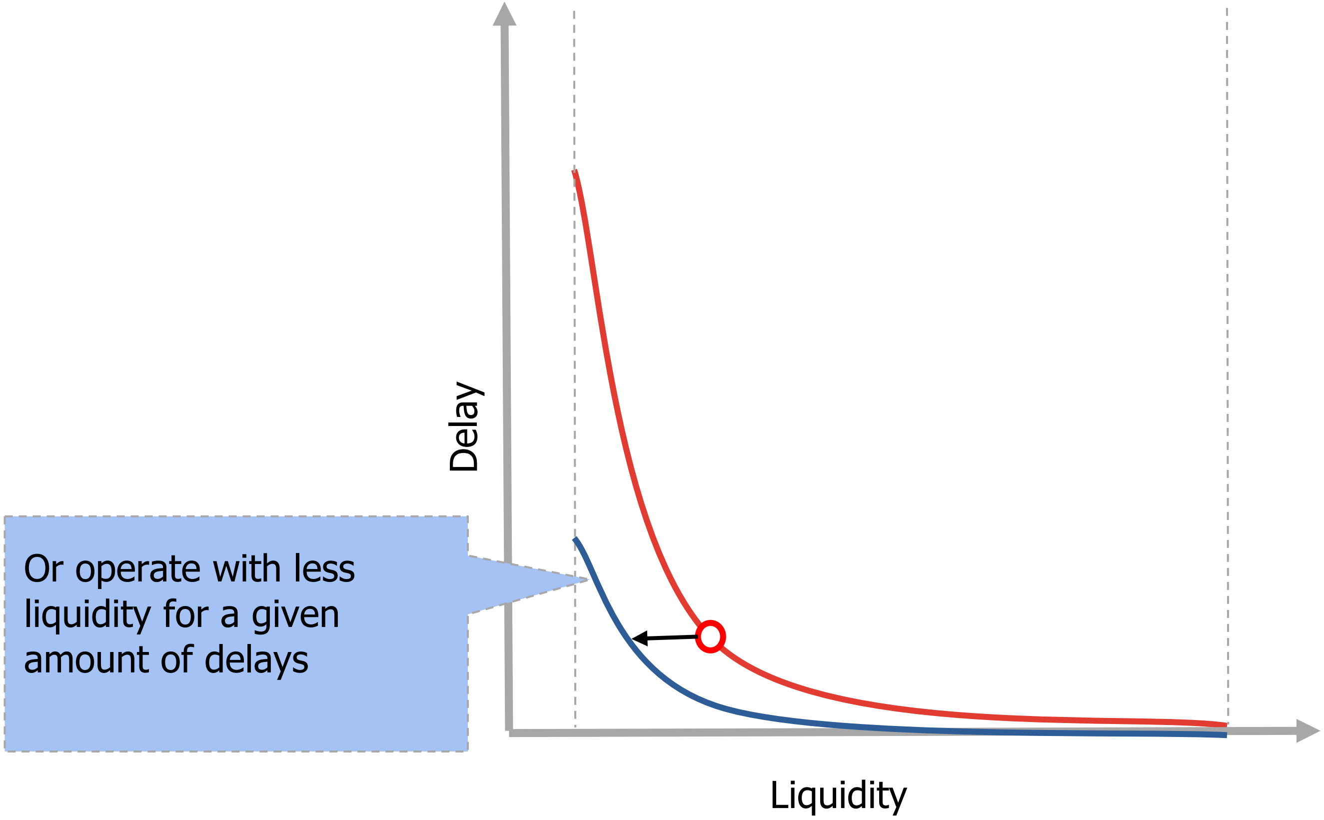
We can find new trade-off curves using different system designs

Liquidity Saving Mechanisms (LSMs)



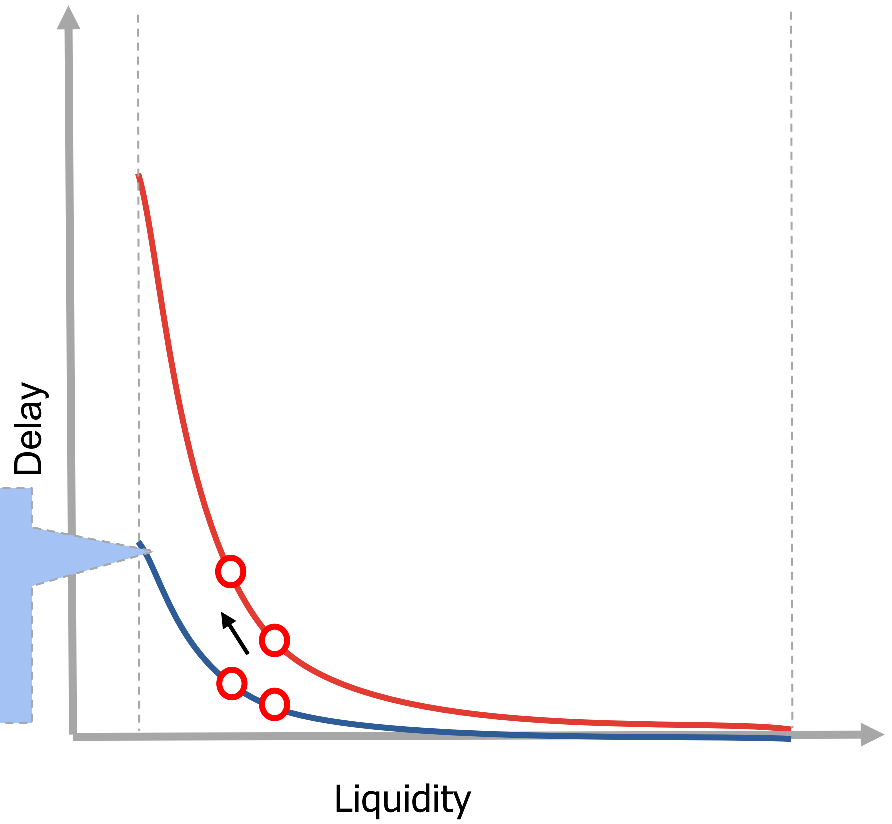
Which will allow the system to settle faster with a given amount of liquidity

Liquidity Saving Mechanisms (LSMs)



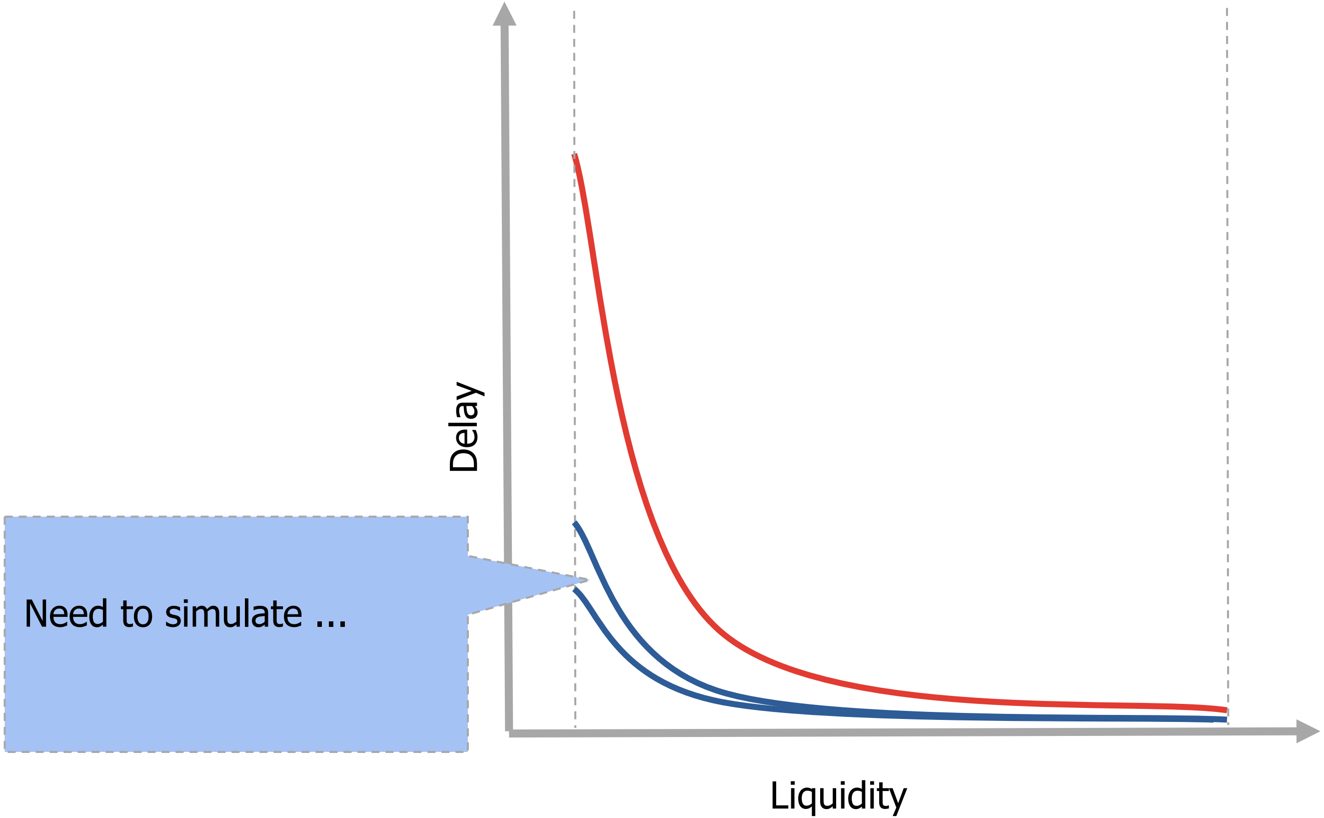
How about stress situations?

Bech and Soramaki (2002). E-money
& Payment Systems Review

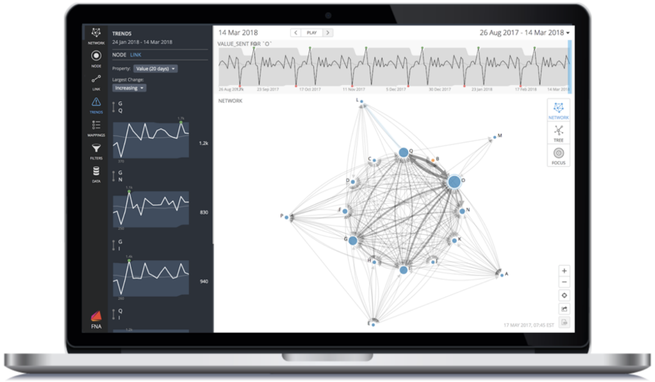


Stress situations reduce liquidity in the system. LSM help alleviate the impact.

Which LSM is the best?



Use Case: Simulating Complex Financial Systems



Payments Canada designs the next-generation interbank payment system with FNA

Background

Payments Canada is in charge of a multi-year project to modernize Canada's Payment system and enable real time payments for the country. Initial estimates predicted a substantial increase in liquidity demands, prompting Payments Canada to consider Liquidity Saving Mechanisms (LSM) for the system.

Objective

Simulation of alternative Liquidity Saving Mechanisms to evaluate how much liquidity needs could be reduced without adding undue operational risks.

Outcome

Simulations with FNA Platform reveal potential liquidity savings worth $4B USD. Payments Canada has now a usable working model for their new service. They will validate the the design with more simulations in 2018, and are planning to expand the FNA Platform to ongoing monitoring and management in 2019.

"The FNA Platform is unique in the marketplace to allow us to design, stress test and monitor a complex system such as our upcoming Lynx interbank payment system"

Mr. Neville Arjani
Director of Research
Payments Canada

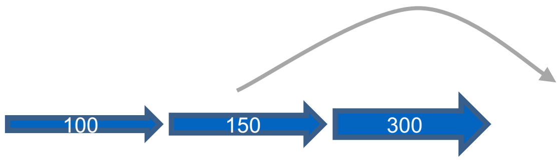
Bypass FIFO

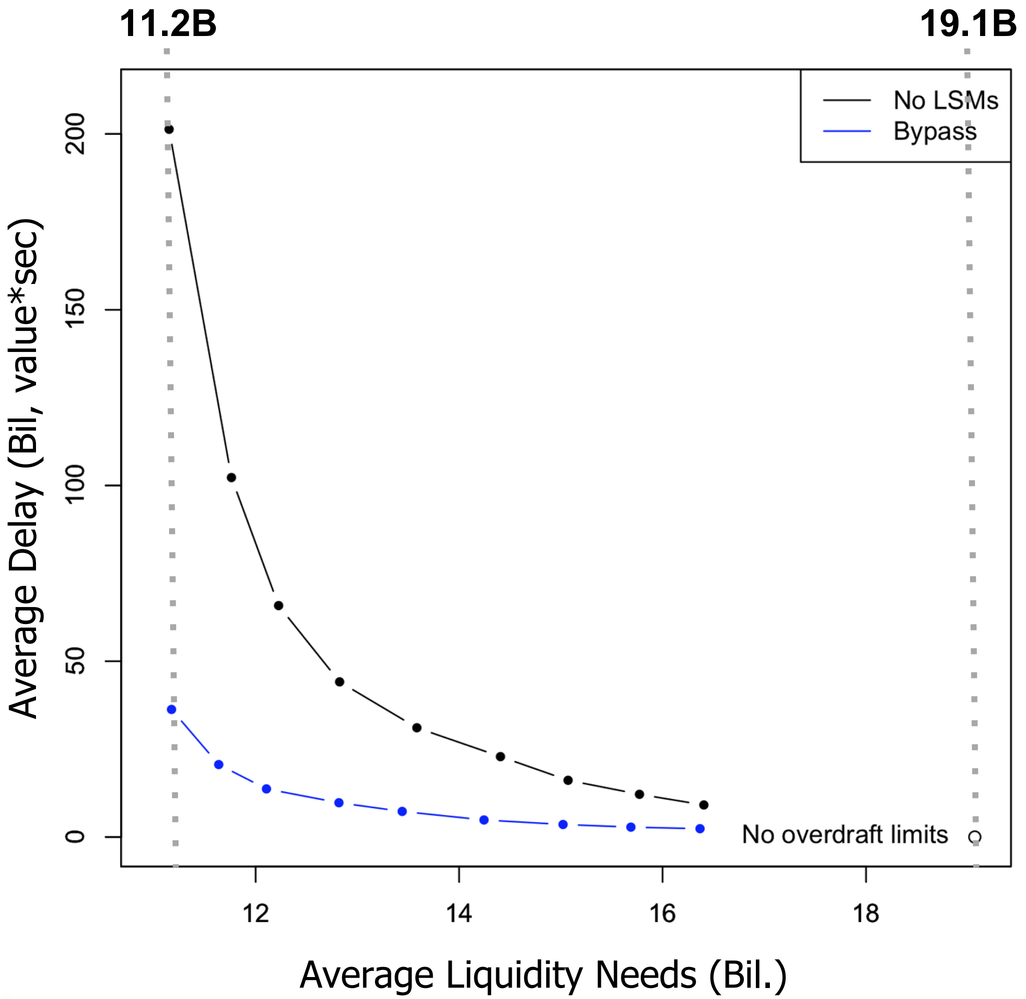
Problem: FIFO order may 'block' settlement if a large payment is at the front of the queue.

Bypass FIFO tries to settle payments down the queue and selects the first one that it finds.

Example: A has liquidity available 200. A has queued payment: 300, 150 and 100.

Payment 150 can be settled.





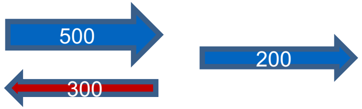
Bilateral Offset

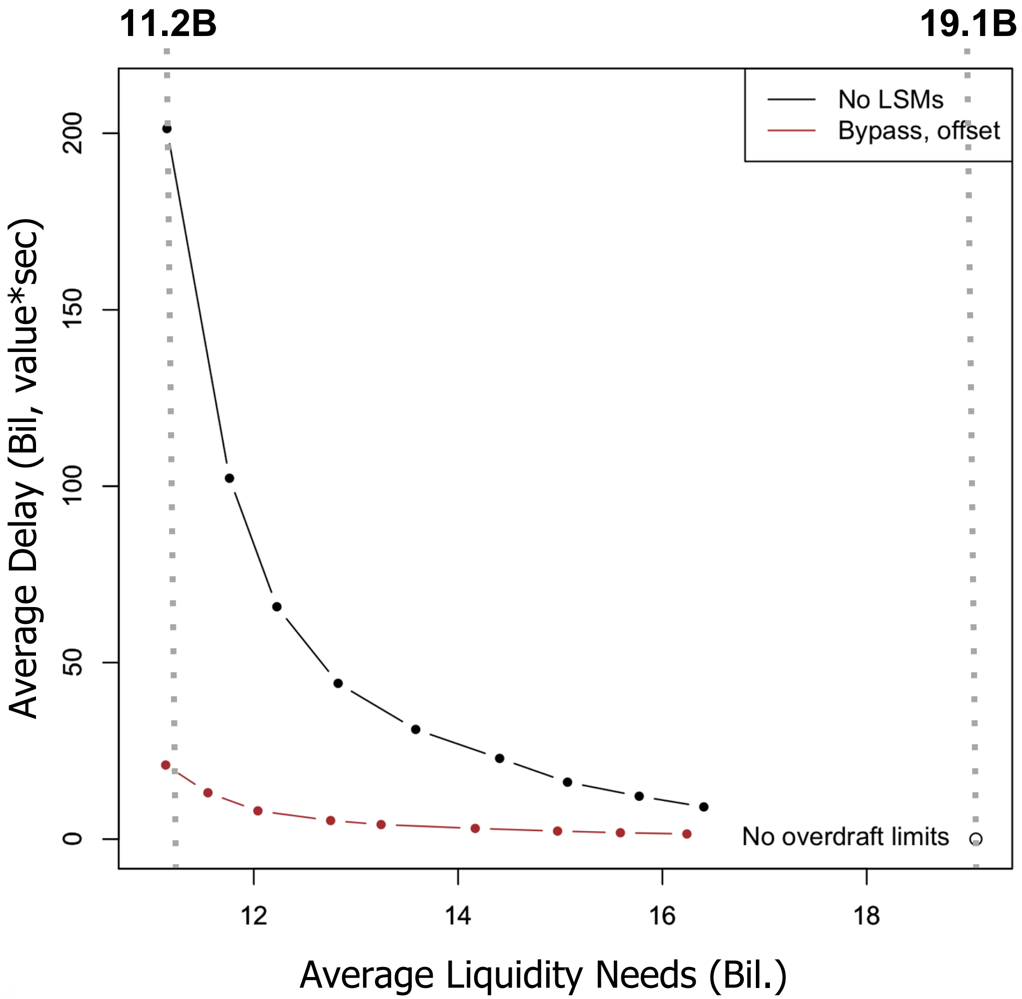
Problem: Liquidity may be unnecessarily used when receiver has payments to sender in its own queue.

Bilateral Offset finds payments from receiver's queue that can be offset with sender's payment.

Example: A has 200 liquidity available and a payment of 500 to B. B has payments to A in queue: 300, 150 and 100.

Payment 500 can be settled offsetting 300 of the 500 against B's payment and the remaining 200 with available liquidity.



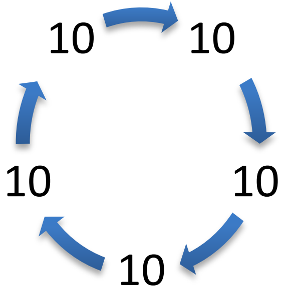


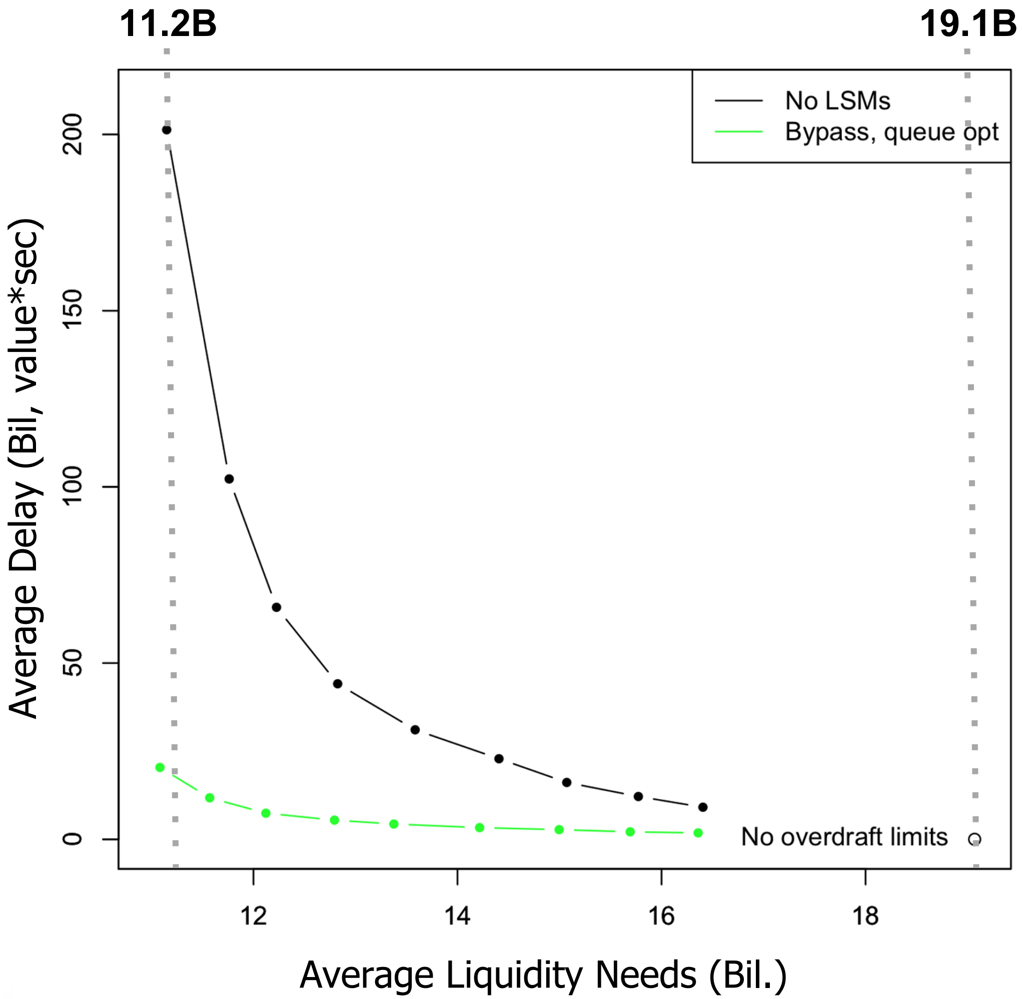
Queue Optimization

Problem: A system may become gridlocked

Queue optimization tries to find a subset of payments that can be settled by all banks with available liquidity through multilateral netting.

Example: A cycle where no bank has liquidity but all payments could be made simultaneously.





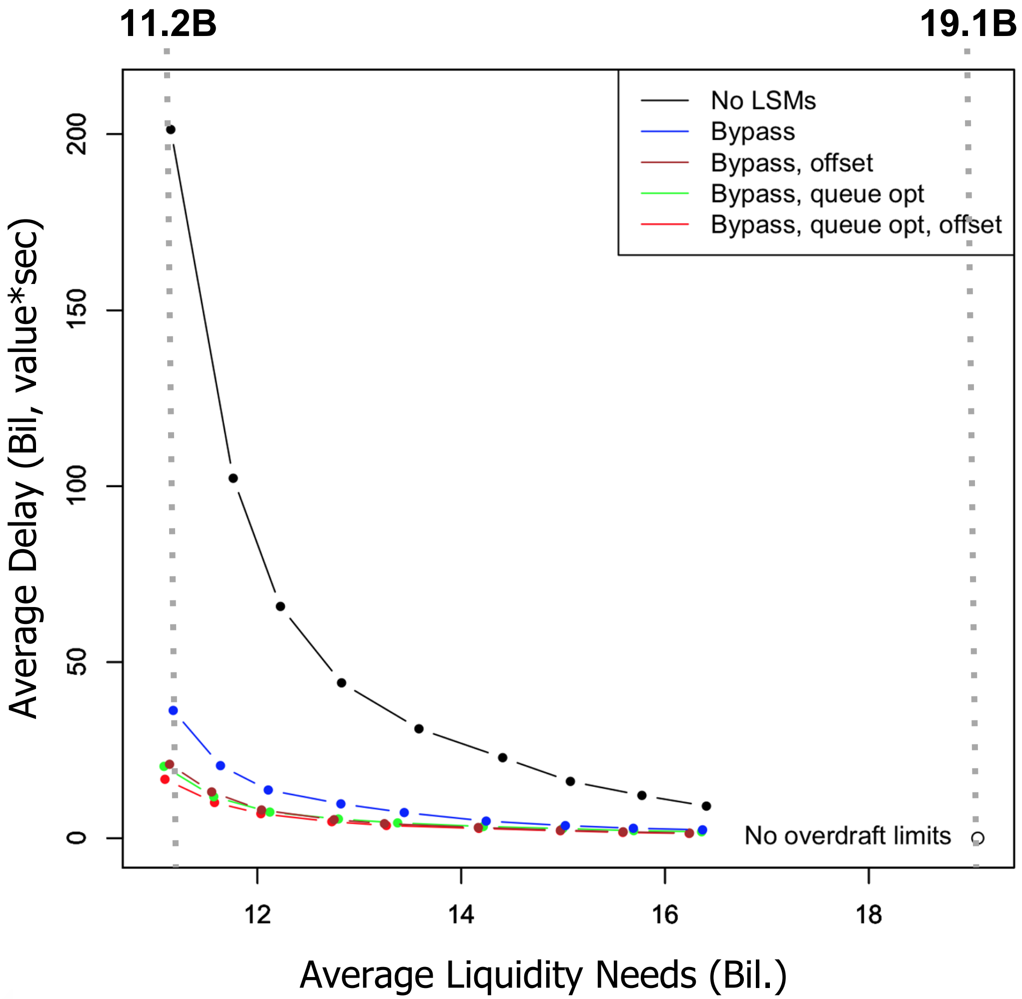
Summary

Bypass alone brings good benefits in reducing delays (or liquidity at a given delay level).

Other LSM's further improve on it.

Bypass + **Bilateral offset** and **Bypass** + **Queue Optimization** are equally efficient.

Having all LSM's running, brings best outcome from a liquidity-delay perspective

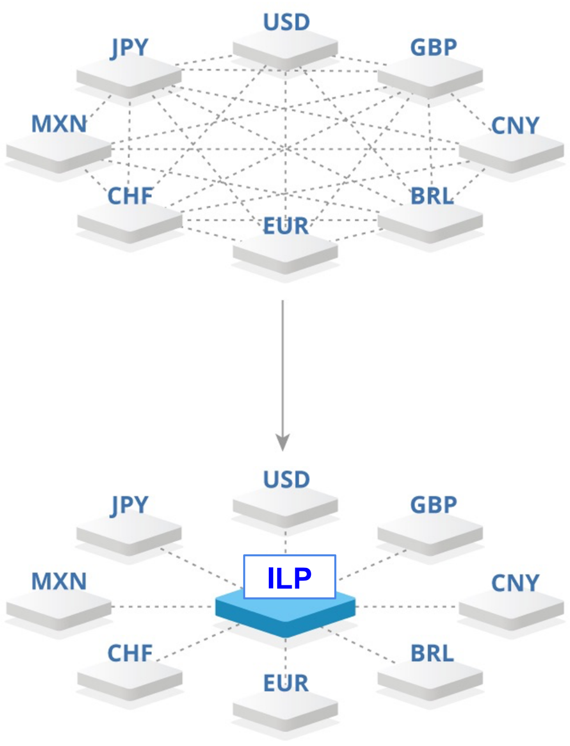


Multiyear Partnership with a Use Case Roadmap

Example:
Payments Canada's partnership with FNA

System Design	Regulatory Approval	Monitoring & What-if	Member Dashboards	AI/ML
Simulate LSMs. Payments Canada uses FNA Platform to simulate LSMs and help decide on design choices.	**Satisfy questions.** Payments Canada uses FNA Platform to satisfy question in the regulatory approval process.	**Monitor and get early warning.** Payments Canada uses FNA Platform to monitor liquidity, detect anomalies and provide early warning.	**Support members.** Payments Canada provides FNA Dashboards to help member institutions in liquidity management.	**Build new AI/ML services.** FNA is Payments Canada's partner for implementing new data analytics & services based on AI/ML techniques.

Use Case: Liquidity Optimisation



Ripple defines liquidity requirements with FNA

Background

Ripple is an RTGS, FX and Retail Remittance system / network which relies upon traditional Nostro / Vostro relationships between its Members. In launching a new service, it needed to prepare the market and its Members for their Day 1 liquidity requirements.

Objective

By using transactional data from the Ripple Members, identify the necessary liquidity per Ripple Member and Ripple Hub and evaluate the impact of liquidity savings mechanisms.

Insights

Ripple used FNA to simulate the liquidity needs of banks interacting over the network over time. That made it possible to determine the required liquidity flows within a hub bank to support the projected network volumes and values and to justify the benefits of the new service/ network.

Use Case: Simulating and modelling new settlement systems

Top banks push ahead with digital coins for 2020

Move draws on four years of research into uses of crypto technology

The 'utility settlement coin' is expected to soon be used for clearing and settling trades

Laura Noonan in New York JUNE 3 2019 25

Thirteen of the world's biggest banks are preparing to launch digital versions of major global currencies in 2020 after years of research convinced them that the technology underpinning cryptocurrencies could be used to make trading less risky and cheaper.

Financial Times, 3 June 2019

Fnality designs, simulates and models optimal system design with FNA

Background

Fnality is a consortium of global banks that is developing a novel asset-backed digital cash instrument for use within global institutional financial markets using DIstributed Ledger Technology.

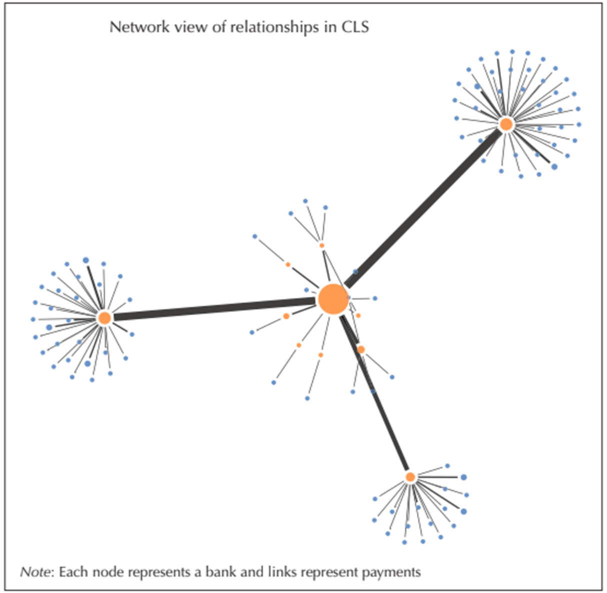
Objective

Fnality is using the FNA Platform to model and simulate the proposed USC ecosystem using realistic individual transaction data from member banks. This allows USC, member banks and regulators to evaluate the impact that system design will have on liquidity requirements and consequently balance sheets supporting the settlement of interbank payments.

Insights

Fnality has used the economic models created with FNA to provide valuable insights to member banks on the overall economic, balance sheet, liquidity and operational benefits of the proposed new service.

Use Case: Determining Liquidity Reduction



"FNA's simulation methodology provided insights that were unattainable via standard balance sheet calculations. The ability to estimate collateral cost savings across an entire payment system was extremely valuable for CLS and also for its customers."

Mr. Peter Lightfoot
UK Head of Risk
CLS

CLS Bank modelled the impact it has on global liquidity cost reduction with FNA

Background

CLS operates a global multi-currency infrastructure to settle FX trades. It is one of the largest Financial Market Infrastructures (FMIs) in the world, settling an average value of $5 trillion each day. CLS wanted to prove to its members the value of the service in not only reducing risk, but also in saving liquidity.

Objective

Measure liquidity savings of the CLS service to its members compared to situation where the FX trades are settled in RTGS systems and by bilateral netting.

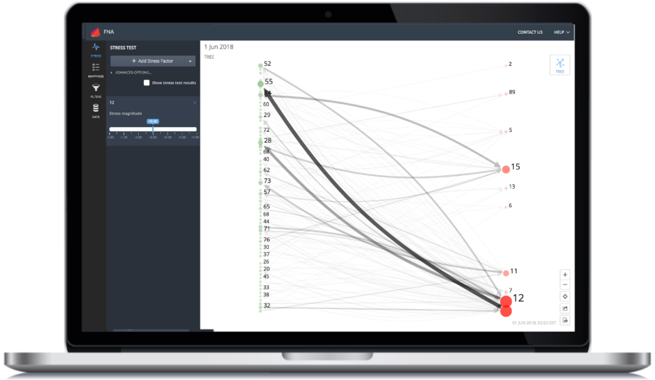
Insights

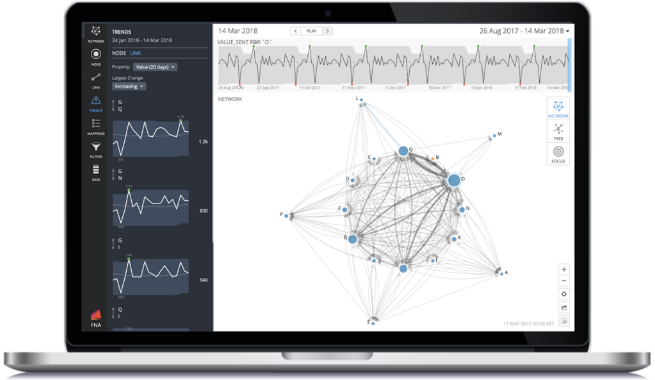
Simulations with FNA demonstrated that CLS provided an estimated annual collateral cost savings of more than $400 million across all of its members.

Case Study "CLS Liquidity Savings" from Book "Network Theory and Financial Risk"

Simulations: Possible Use Cases

1. System Design
2. Evaluate Changes in Environment
3. Model Validation
4. Stress Testing & Scenarios
5. Targeting Remediation Actions
6. Prediction / Forecasting
7. Recovery





Use Case: Simulating Complex Financial Systems

CLS demonstrates liquidity savings resulting from its netting service

Background

CLS operates a global multi-currency infrastructure to settle FX trades. It is one of the largest Financial Market Infrastructures (FMIs) in the world, settling an average value of $5 USD trillion each day. CLS wanted to prove to its members the value of the service in not only reducing risk, but also in saving liquidity.

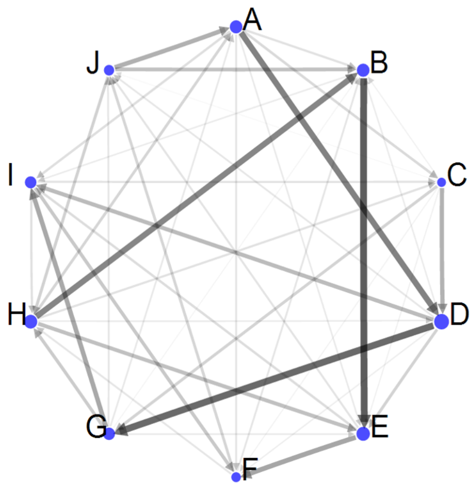
Objective

Measure liquidity savings of the CLS service to its members compared to situation where the FX trades are settled in RTGS systems and by bilateral netting.

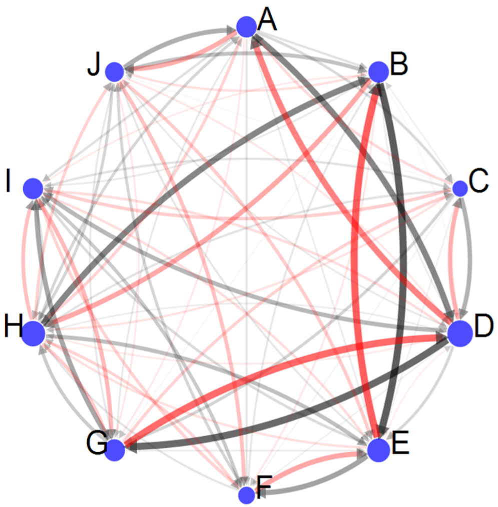
Outcome

Simulations with FNA demonstrated that CLS provided an estimated annual collateral **cost savings of more than $400 million** across all of its members.

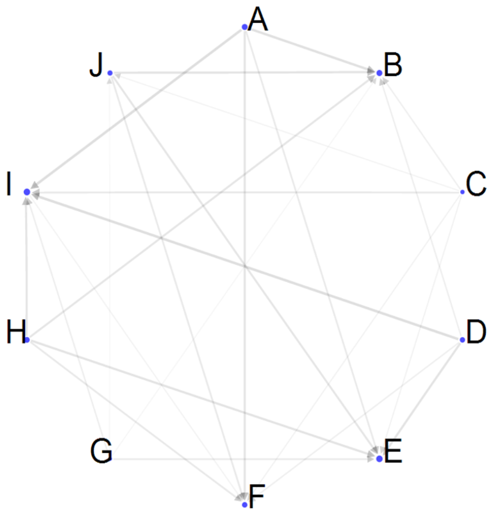
Multilateral Netting without Central Agent



Bilaterally offset liquidity needs



New payments aimed at minimizing multilateral positions



Bilaterally offset, reduced liquidity needs

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