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
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
Agent Based Models

Existing literature

- 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
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 (e.g., do larger participants send larger payments)
- System stability (net flows over longer times)
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)
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

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**
There is an amount of liquidity each bank must have to complete settlement.

And another amount above which adding more has no impact.
End-of-day net settlement, 5-20%  

RTGS without delays, 100%  

Delay  

Liquidity
Liquidity Delay

Initially reducing liquidity has little impact. Eventually the system becomes increasingly gridlocked (chaotic).


A convex shape for trade-off
Institutional aspects matter

System with many time-critical payments or other constraints
Network topology matters

- Small number of highly connected participants
- Large number of evenly connected participants
In theory we have some optimal allocation of liquidity that depends on the costs of liquidity and delays.

Where should we be on this curve?
Liquidity distribution matters

But the liquidity will likely not be optimally allocated among participants
Liquidity distribution matters

So we find a point that has more delays than optimal.
Incentives matter

In addition, if liquidity is sufficiently costly, participants are likely use less liquidity than optimal for the whole system.

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

How do we foster co-operation?

Throughput guidelines, liquidity groups, building confidence, norms, monitor free-riding, etc.
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)

Or operate with less liquidity for a given amount of delays
How about stress situations?

Liquidity

Delay

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

Bech and Soramaki (2002). E-money & Payment Systems Review
Which LSM is the best?

Need to simulate ...
Use Case: Simulating Complex Financial Systems

"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

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.
**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.

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![Graph](image)
**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

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

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

**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.

"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

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

Background
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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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