BoF-PSS2 - experienced users workshop

7th payment and settlement system simulation seminar

24 August 2009

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Agenda of the experienced users pre seminar workshop

- Background and introduction
- Management of data and large simulation projects
  - Demo 1: Command line interface and output queries
- Algorithms
- Network analysis with BoF-PSS2
  - Demo 2:
- Agent based models with BoF-PSS2
  - Demo3: Simple ABM with simulator without coding
- Brainstorming and discussion on development possibilities and user experiences

Introduction and run-through of best practices in using BoF-PSS2

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Technical issues

- Workshop assumptions
  - Some prior experience of BoF-PSS2 use
  - Familiarity with payment system terminology
  - Good computer literacy
- References from these slides
  - BoF-PSS2 user manual, version 2.4.0 (UM)
  - BoF-PSS2 Descriptions of databases and files, version 2.4.0 (DB)
  - BoF-PSS2 Command line interface user manual (CLI)
  - BoF-PSS2 Algorithm descriptions and user module development guide, version 2.4.0 (ALG)

Included in the workshop handout

Background of BoF-PSS2

EUROJÄRJESTELMÄ
EUROSYSTEMET

Bank of Finland...
- National central bank and monetary authority
- Member in European System of Central Banks
- Long tradition as a research oriented CB
- Statutory task to "participate in maintaining the reliability and efficiency of the payment system and overall financial system and participate in their development"

... Payment system simulator
- BoF-PSS1 was built before Finland joined European Monetary Union (1.1.1999)
- BoF-PSS2 was released in 2004 (beta 2003)
  - Specialised tool for payment system experts
  - Easy to use, versatile and modular
  - Designed to be shared with others
  - Available free of charge for research purposes

BoF and BoF-PSS2

- Central node of the user community:
  - Annual international simulation seminars since 2003
  - Procedings publications collecting payment system studies
  - Simulator home pages: www.bof.fi/sc/bof-pss
    - BoF-PSS2 documentation
    - Links to published studies
    - Presentations from all previous seminars
  - Extranet https://extranet.bof.fi/bof-pss2
- Development of the tool
  - Co-operation and sponsorship projects with simulator users are possible
- Support services
  - Help desk, consultation, training etc.

Why simulate payment systems?

"Simulations start where analytical methods fail"

- **Complex systems**
  - **Replication of the processing logics in the grassroots level**
  - **Real and massive data sets can be used**
- **Interactive setups**
  - **Feedback loops: queues or (behavioral) reactions**
  - **Conditional rules**
- **Setups where the time aspect is important**
  - **Changes in system state: liquidity levels, batch runs**
  - **Order of events**
  - **Simulation requires a time sequence to be defined**

Analytical models may need to be too simple to be practically useful

…but there are also other advantages

Simulation as a learning exercise
- Modelling requires exact knowledge of how systems are built
- Results are tested against expectations – often the expectations are not valid
- Studying the systems reveals how they are *actually* used

Simulations are powerful method for communication
- Concretisation and visualisation
- Possibility of interactive participation
- Example: transition to a new system with network externalities

Situations which are infeasible to test in real life can be simulated
- Various risk scenarios
- Possible changes in settlement conventions, methods and pricing
- Changes in behavioural patterns and official policies

Objectives: Learn, analyse, quantify

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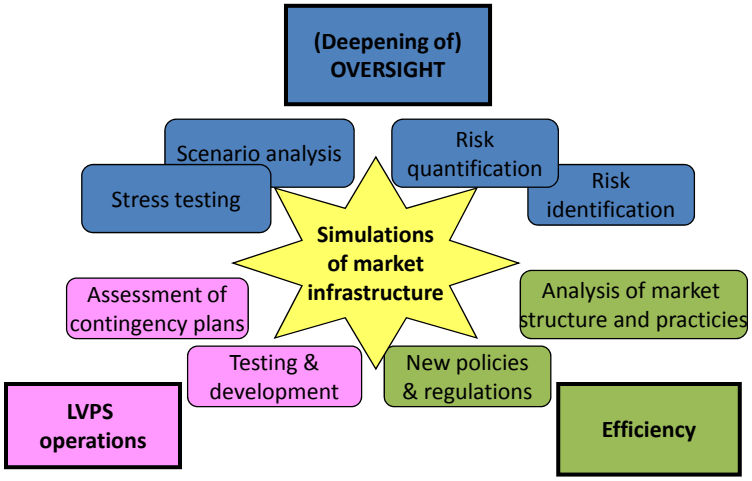
Purposes of simulations



Simulations are well suited for multiple CB tasks

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How BoF-PSS2 has been used, some examples

- Countries and systems discussed in CPSS (2005): "New developments in LVPS", BIS

Country	System	CB has BoF-PSS2	Publicly available analyses with BoF-PSS2
Belgium	Ellipsis, TARGET2	Yes	Stress test
Canada	LVTS	Yes, Sponsor	Stress tests, new setup proposals, efficiency studies, regular oversight
France	PNS, TARGET2	Yes	Own simulator for PNS, Algorithm comparisons, "cost of FIFO", Target2 simulator (Ongoing)
Germany	RTGSplus, TARGET2	Yes	Target2 simulator (Ongoing)
Hong Kong	Chats	Yes	- *
Italy	Bi-Rel, TARGET2	Yes	Target2 simulator (Ongoing)
Japan	BoJ-Net	Yes, BoF-PSS1	Impact of changes in accounts or settlement algorithms
Netherlands	TOP, TARGET2	Yes	Stress test, Network topology
Singapore	MEPS	Yes	- *
Sweden	E-RIX	Yes	Liquidity studies
Swiwerland	SIC	Yes	Stress testing
UK	Chaps	Yes, Sponsor	Stress test, Tiering structure, LSM's vs bank behaviour etc.
US, FeD-NY	Fedwire	Yes, sponsor	SSS, change in intraday liquidity policy, network topology, behavioral studies etc.

* No studies with publicly available results known by the speaker for the moment

Management of data and large simulation projects

Basic workflow of BoF-PSS2 use

From input data to output statistics through replication of process logic of the payment system under study

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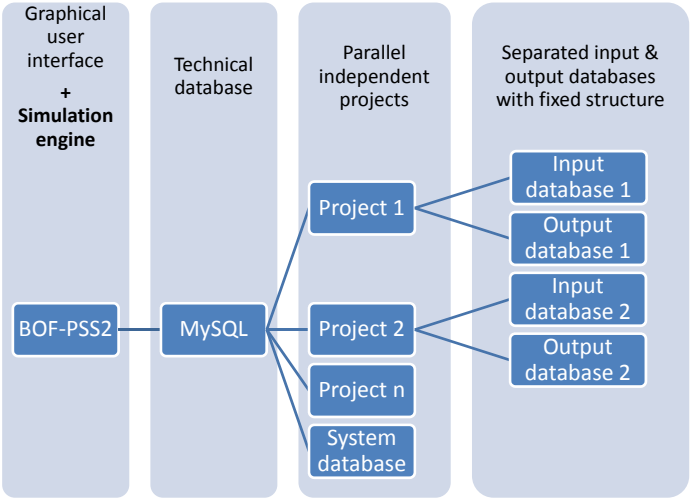
Overall data structure in BoF-PSS2



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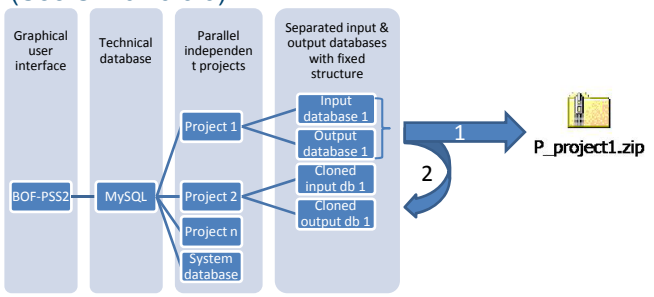
Based on the structure (1)

- Same installation can be used by multiple persons
  - Workstreams in own projects
  - No access control / security facilities
- Easy back up (1) of cloning (2) of projects
  - (See UM ch 3.3.3)



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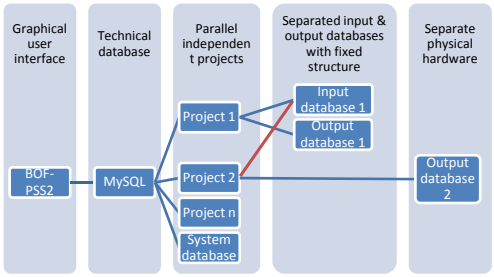
Based on the structure (2)

- Sharing of databases between projects is possible (1)
  - Useful eg if big number of scenarios / combinations are computed from same source data
- Nondefault locations (e.g. Network drive) of data (2)
  (see UM ch 3.3 for instructions on working with projects)



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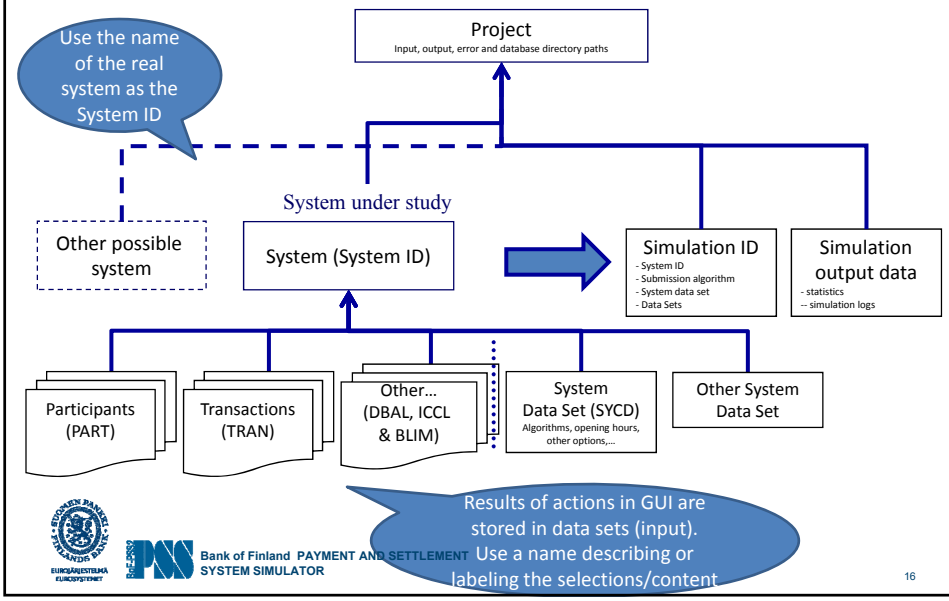
What goes in to the database

- Data
  - Transactions, participants, balances, credit or bilateral limits, (reservations)
  - i.e. The account structure, bookings and constraints affecting the settlement process
  - Also optional data fields and user defined or meta data
- System definitions
  - Type of system: RTGS, continuous netting, deferred netting
  - General parameters
  - Process logic, which is
    - Divided into algorithms classes: Entry, queue release etc.
    - Composed by selecting appropriate algorithm for each needed class.
  - Multiple separate and interlinked systems are possible

Organization of input data



Simulation management tools, bypassing the GUI part 1: data handling

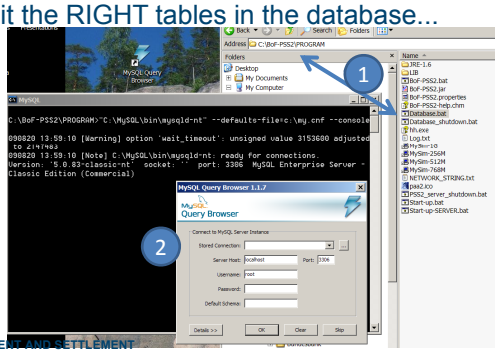
- Database structure allows direct use of the database
  - Link the simulator output directly to preferred analysis software:
    - Access, SAS, Matlab, Stata, ... (MySQL ODBC link or direct database connection)
  - Make tailored direct queries to database
    - See e.g. Example on direct computing of statistical indicators (Seminar 2008, Advanced users workshop material available in the extranet)
  - Housekeeping: delete unnecessary projects, templates, usermodules etc.
    - See UM ch. 3.3.4 and ch. 5.2
- Demo 1, part2 (comming soon)

Simulation management tools, bypassing the GUI part 2: simulator tasks

- Command line interface
  - Possibility to bypass graphical user interface in repetitive tasks
  - Possibility to integrate BoF-PSS2 into 3rd party software e.g. Optimisation routine
  - Automation of repetitive tasks e.g. Weekly or monthly calculation of simulation based indicators
- Stable version of CLI included starting from version 2.4.0
  - See ”BoF-PSS2 Command line interface user manual”
- Demo 1, part 1

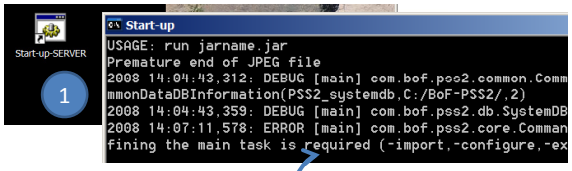
Demo 1, starters

- Simple use of database tools
  - How to do maintenance tasks in the database (see UM ch 5.2)
  1. Open the database (simulator not running)
  2. Open a database viewer/editor (here MySQL Query browser)
  3. Browse and edit the RIGHT tables in the database...

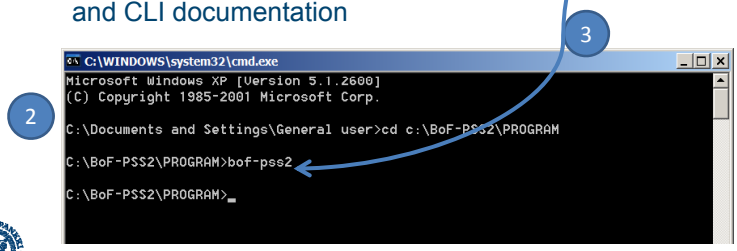


More starters

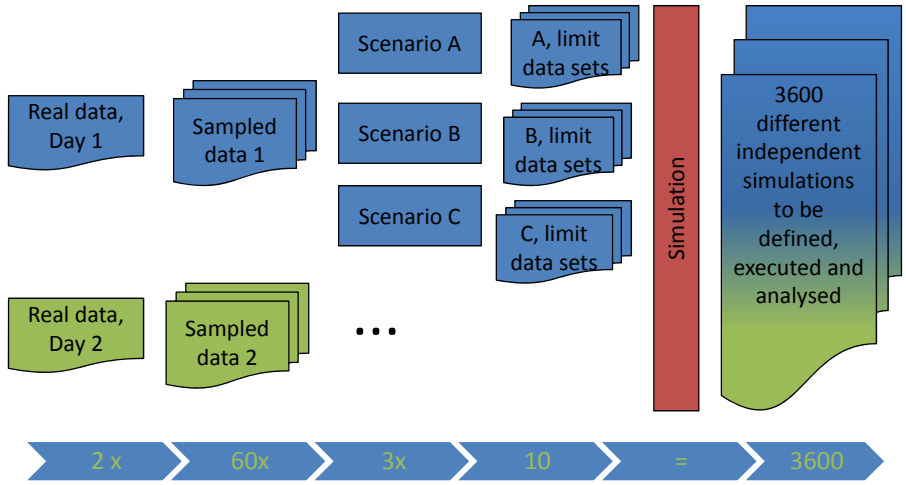
- CLI "Hello world"
  1. Start the simulator in server mode



  2. Open a command prompt in c:\bof-pss2\program\
  3. Try commands starting from "Bof-pss2", follow the feedback and CLI documentation



The real demo case, Data preparation setup



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Demo setup explained

- Things to be completed in this project
  - Import of 120 transaction data sets (4 months of separate days)
  - Import of 30 bilateral limit data sets (10 for each scenario)
  - Configuration and execution of all 3600 combinations
  - ⇒ Normal scenario analysis with variations along multiple variables
- What is needed
  - Command line interface
  - Scripting tool for constructing the commands
  - A clear systematic naming convention of data sets and simulations
- Demo:
  - Use of Excell or Matlab in constructing the CLI scripts

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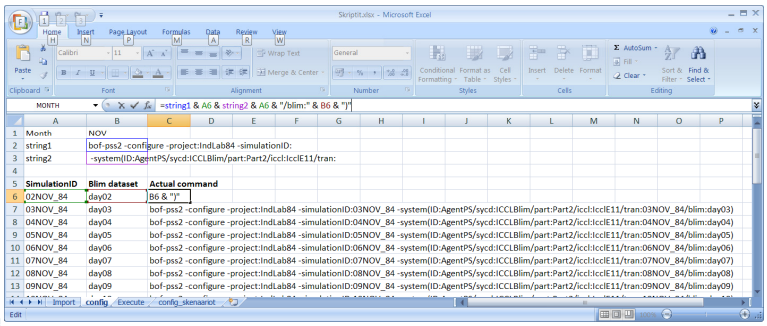
Excell example

1. CLI commands created in spreadsheet, here 31 simulations configured
2. Script into txt file (example.txt)
3. bof-pss2 –commandfile:example.txt

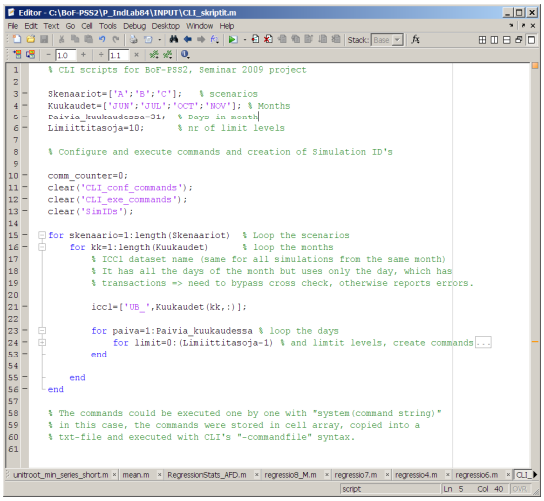


Matlab example

- Configuration and execution commands of 3600 simulation with few for-loops
  - Actual commands similar as in the excell case
- The same script could also execute the individual commands

- All commands give return value
  - 0: unsuccesfull
  - 1: succesfull

See CLI_script.m file in handout

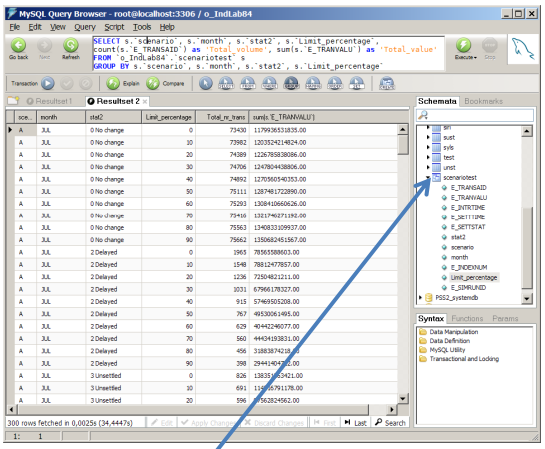


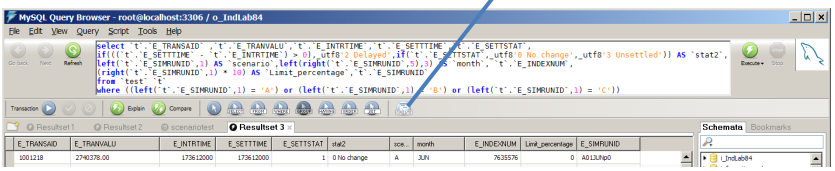
Summarising the results of 3600 independent scenarios

Tailored queries to output database are used

- Intermediate results into view "scenariotest"
- Final results with one query
  - Aggregation (sum and count) based on Scenario, Month, transaction settlement status2 (indicator created in intermediate query) and limit level
- Results can be exported e.g. To Excell

- Details in the screenshots

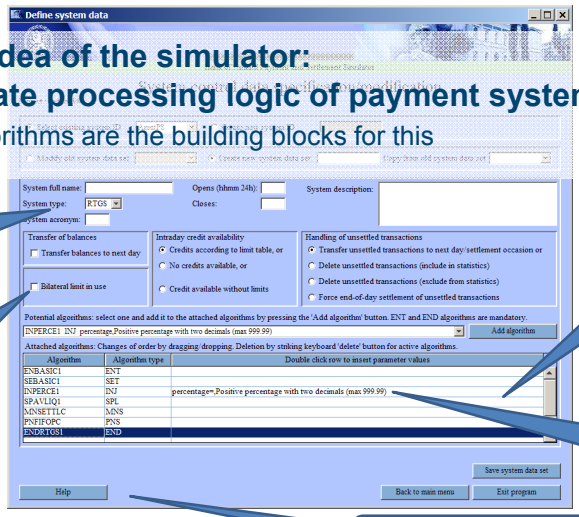




Algorithms

Algorithms in BoF-PSS2

- **Core idea of the simulator: replicate processing logic of payment systems**
  - Algorithms are the building blocks for this



Available ones depend on the system type

...and on some system specifications

Order of the algorithms is significant

Parameters allow customisation

Descriptions in the integrated help and in technical documentation (ALG)

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The building blocks of settlement logic in BOF-PSS2

Main algorithms

- **Submission :** What happens next?
- **Entry:** Initial processing for transactions: settle immediately if possible, call sub algorithms if defined or send to queue.
- **Settlement:** Call sub algorithms to settle transactions from queue.
- **End:** Perform final procedures of day or settlement period.

Common for all systems simulated concurrently

Sub algorithms

- **Queue**:Settle individual transactions from queue in defined order.
- **Partial Net Settlement** (PNS): Settle a subset of queued trans
- **Multilateral Net Settl.** (MNS):Settle queues with "All or nothing"
- **Bilateral offsetting:** Match entered payments with queued payments having opposite direction (sender & receiver)
- **Splitting**: Split larger trans into sub-transactions
- **Injections**: Perform liquidity transfers between defined accounts

Logics of one individual simulated system.

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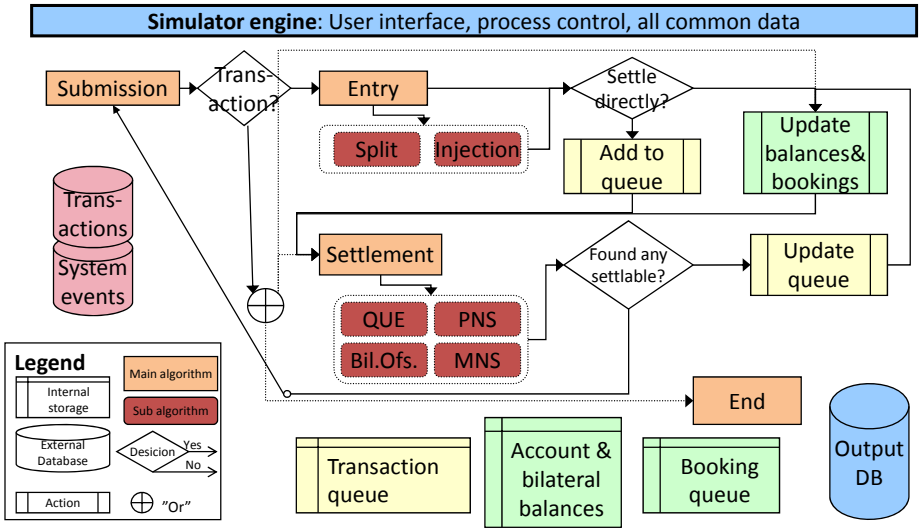
RTGS process



Subalgorithms are executed in the same order which they have in system definition

Expanding the algorithm list

- Current algorithms are open source
  - Users can develop own algorithms with user module interface
  - Modular design of algorithms and interfaces facilitates easy expansion
  - See Javadoc of BoF-PSS2, User module development guide and tutorial examples (available in home pages / extranet)
  - Source codes: c:\bof-pss2\modules\
- User interface, simulator core and data structures are closed source
  - Development projects coordinated by BoF
  - Outsourced programming
  - Good references from sponsorship projects (BoC, FeD-NY, BoE,...)

Network analysis with BoF-PSS2

Network analysis tools

- Simulator's network analysis features is using an external Loki toolkit
  - Developed by Sandia National Laboratories
  - Based on Open source Java libraries (Jung, Repast,...)
  - Tailored for analysis of infrastructures such as payment systems
- Strengths
  - Time series can be automatically calculated
  - Large number of network indicators
- Simulator provides additionally
  - Seamless integration into simulator databases (input and output) – Use the same data easily
  - Graphical user interface for using Loki

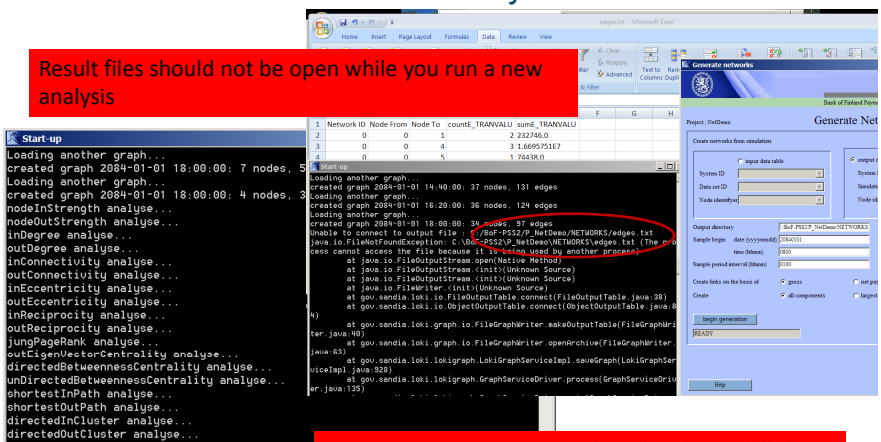
Demo

- Data from the previous Demo case, one particular day
  - Input side: network and analysis of initial transactions
  - Output side:
    - Network and analysis of settled transactions in two extreme scenarios
    - Network of unsettled transactions similarly
- Analysis and comparison of indicators in separate application

  (Actual results presented in the seminar Wednesday afternoon)
- No CLI commands for network analysis features
  - Possibility to directly use the Loki program for advanced users

Some issues to know when using v 2.4.0 network analysis features

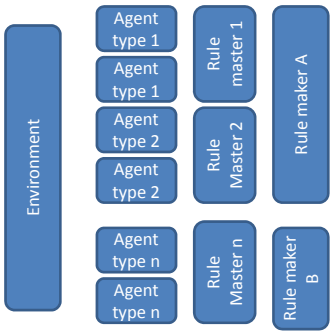
Result files should not be open while you run a new analysis



Some computations can be lengthy, do not kill the process

Agent based modelling with BoF-PSS2

Agent based modelling (ABM), generic framework and BoF-PSS2



One generic conceptual framework of ABM model structure
- Environment
- Agents
- Agents logic or rules

Source: Terna P. (2000), Economic experiments with SWARM...

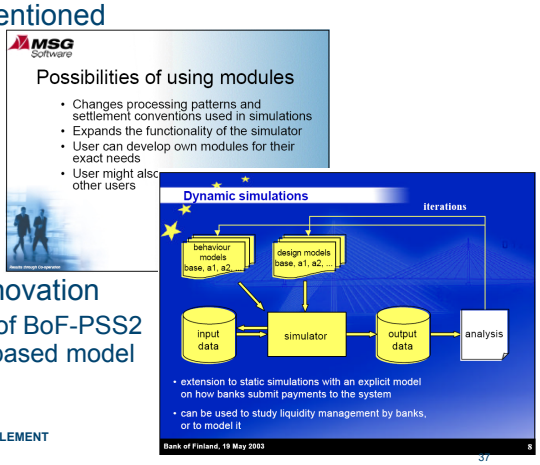
- BoF-PSS2 can serve in payment system ABM's as a realistic and versatile model of the environment

Integration in agent based models

- Common approach with BoF-PSS2 so far has been deterministic event based simulations
- Two alternatives were mentioned already in 2003

1. Integrate with external dynamic model
2. Modify the algorithms and include e.g. Agent based modeling elements

- 3rd possibility is new innovation
  - Using existing features of BoF-PSS2 as a "simulated" agent based model (Demo continued)



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Solution 1, external dynamic model

- Independent agent based model, which creates input data or parameters: small economy, artificial exchange...
- BoF-PSS2 as a model of the settlement system
  - Integration with the external model with data files in specified locations
  - BoF-PSS2 has command line interface

  ⇒ automated simulation runs can be started from the external model

- Benefits
  - No limitation for the tool used in the external model
- Disadvantages
  - Currently only file based batch run approach is supported

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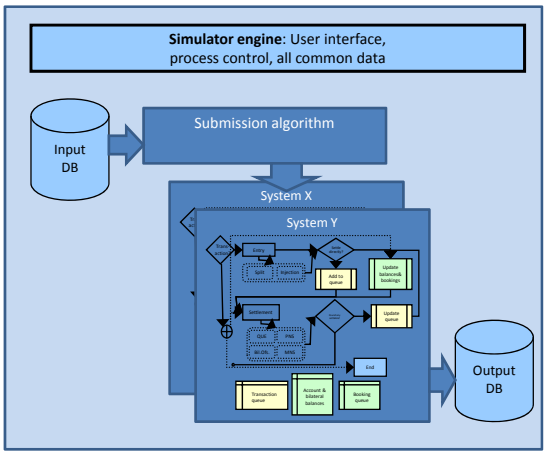
Solution 2: user module changes

Recall that

- •Process logic is splitted into algorithm classes
- •Existing algorithms are open source code
- •Users can easily* include own modules

Logical place for an agent based model is in the submission algorithm: ”What happens next in the simulated setup”



*See the following:

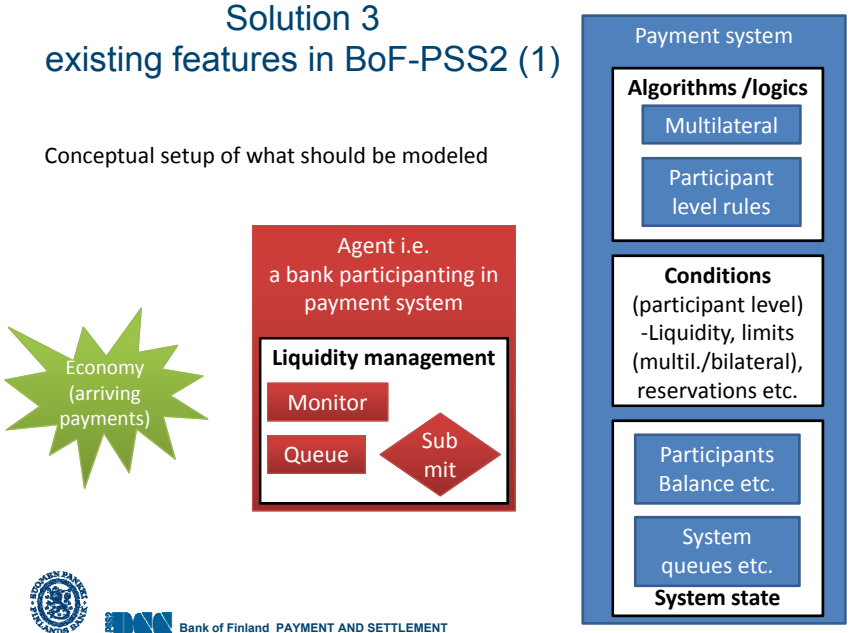
- •Algorithm descriptions and user module development guide
- •Source code for all algorithms can be found in the simulators home pages or installation folder
- •Step by step demo in the simulator extranet (only for licenced users though)

User modules solution continued

- Benefits
  - Allows the ABM to react on internal state variables of the settlement system on transaction level
  - Use of Java based toolboxes possible
    - Repast, Jawa Swarm…
  - Succesfull new algorithms can be distributed to wide user community
  - BoF is open for joint project proposals – good track record from sponsorship projects for enlarging the capabilities of BoF-PSS2
- Disadvantages
  - BoF-PSS2 is not fully open source; engine, interfaces and main data structures can’t be changed by the user

Solution 3
existing features in BoF-PSS2 (1)

Conceptual setup of what should be modeled



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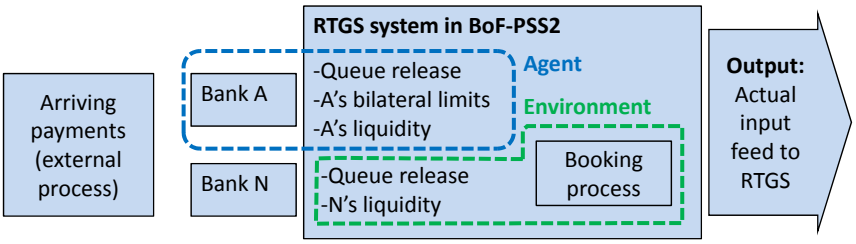
Solution in BoF-PSS2 without programming

- Agents internal process is described with **participant level features** in a BoF-PSS2 model



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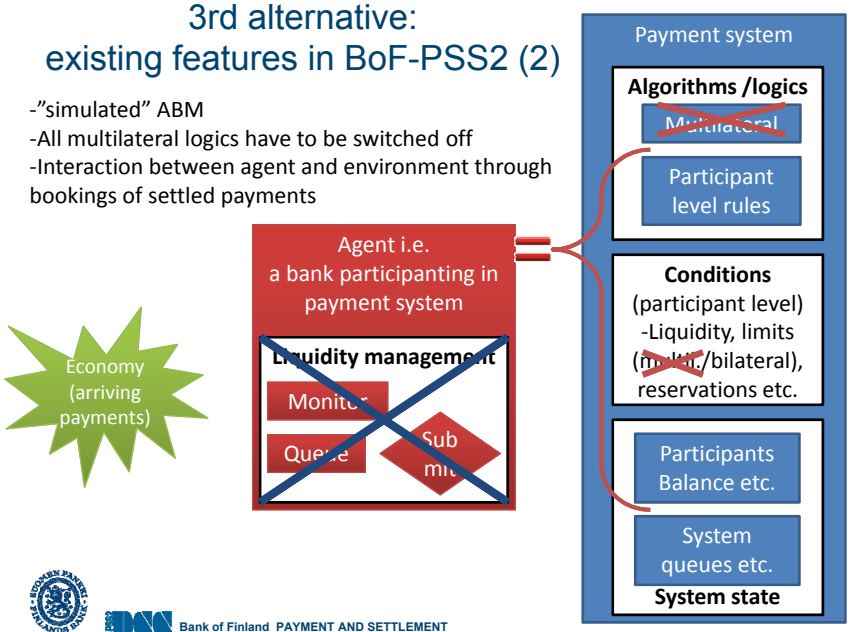
3rd alternative: existing features in BoF-PSS2 (2)

-"simulated" ABM
-All multilateral logics have to be switched off
-Interaction between agent and environment through bookings of settled payments



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Simulated ABM with BoF-PSS2

- Benefits
  - No programming needed, easy to start
  - Several realistic rules available – same functions often exist in centralised and de-centralised setups
    - Counterparty sending limits (Bilateral limits)
    - Multilateral sending limits (multilateral blim)
    - FIFO or Bypass-Fifo participant level queue
    - Receipt reactive logic
    - Reservations (forthcoming)
  - Possibility to introduce user modules i.e. Enriched agent level logics
- Disadvantages
  - Multilateral logics have to be disabled
  - Conceptually not so clear – requires a careful implementation

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Brainstorming and discussion of development possibilities

Brainstorming main topics

1. Simulator as my tool
2. My greatest problems with BoF-PSS2
3. What would I like to simulate in my wildest dreams

Brainstorming groups

- Group 1:
  - Andersen, Arciero, Ferrari, Heijmans, Lindner, Renault, *Hellqvist*
- Group 2:
  - Denbee, Hancock, McLafferty, Pineta, Rasmussen, Tao, Koskinen
- Group 3:
  - Heuver, Lovin, Picillo, Sin, Yong, *Laine*,

Extra materials

Input database

- What tables or fields are there and what is their intended purpose
- See also Database documentation (DB)

Transaction data (1)

Field name	Detailed name	Required
T_DATSETID	Data set ID	Y
T_SYSTEMID	System ID	Y
T_TRANSAID	Transaction ID	Y
T_INTRDATE	Introduction date	Y
T_INTRTIME	Introduction time	Y
T_TRANVALU	Transaction value	Y
T_FRSYSTID	From system ID	Y
T_FRPARTID	From participant ID	Y
T_FRACCOID	From account ID	Y
T_TOSYSTID	To system ID	Y
T_TOPARTID	To participant ID	Y
T_TOACCOID	To account ID	Y
... continued		

Identifier information

- DATSETID to enable the importing of parallel data sets
- SYSTEMID to identify the system in which the payment is submitted
- TRANSAID to uniquely identify each payment

Transaction data (2)

Field name	Detailed name	Required
T_DATSETID	Data set ID	M
T_SYSTEMID	System ID	M
T_TRANSAID	Transaction ID	M
T_INTRDATE	Introduction date	M
T_INTRTIME	Introduction time	M
T_TRANVALU	Transaction value	M
T_FRSYSTID	From system ID	O
T_FRPARTID	From participant ID	M
T_FRACCOID	From account ID	O
T_TOSYSTID	To system ID	O
T_TOPARTID	To participant ID	M
T_TOACCOID	To account ID	O
... continued		

- The date and time the payment is actually submitted to the system depends on the submission algorithm used
- The submission algorithm available now submits the payment to the system according to the date/time set here
- The original value of the transaction (two digits)

Transaction data (3)

Field name	Detailed name	Required
T_DATSETID	Data set ID	M
T_SYSTEMID	System ID	M
T_TRANSAID	Transaction ID	M
T_INTRDATE	Introduction date	M
T_INTRTIME	Introduction time	M
T_TRANVALU	Transaction value	M
T_FRSYSTID	From system ID	O
T_FRPARTID	From participant ID	M
T_FRACCOID	From account ID	O
T_TOSYSTID	To system ID	O
T_TOPARTID	To participant ID	M
T_TOACCOID	To account ID	O
... continued		

- The system, participant/account the payment is debited from (T_FR...) and credited to (T_TO...)

Transaction data (4)

... continued		
Field name	Detailed name	Required
T_ASSENAME	Asset name	N
T_DESCRIPT	Description	N
T_LINKCODE	Link code	N
T_LINKSYST	Linked system	N
T_TRANCLAS	Transaction class	N
T_USERDEID	User defined ID	N
T_USERCOD1...5	User defined codes 1...5	N
T_PRIORITY	Priority	N
T_PROCTYPE	Processing type	N
T_PROCDATE	Processing date	N
T_PROCTIME	Processing time	N

- The name of the asset stored on the account (e.g. NOK1V for Nokia shares) and its description

Transaction data (5)

... continued		
Field name	Detailed name	Required
T_ASSENAME	Asset name	O
T_DESCRIPT	Description	O
T_LINKCODE	Link code	O
T_LINKSYST	Linked system	O
T_TRANCLAS	Transaction class	O
T_USERDEID	User defined ID	O
T_USERCOD1...5	User defined codes 1...5	O
T_PRIORITY	Priority	O
T_PROCTYPE	Processing type	O
T_PROCDATE	Processing date	O
T_PROCTIME	Processing time	O

- The PVP and DVP mechanisms match the two legs on the basis of a unique link code attached to them
- For such transactions the code and the system where the corresponding transaction can be found must be provided

Transaction data (6)

... continued		
Field name	Detailed name	Required
T_ASSENAME	Asset name	O
T_DESCRIPT	Description	O
T_LINKCODE	Link code	O
T_LINKSYST	Linked system	O
T_TRANCLAS	Transaction class	O
T_USERDEID	User defined ID	O
T_USERCOD1...5	User defined codes 1...5	O
T_PRIORITY	Priority	O
T_PROCTYPE	Processing type	O
T_PROCDATE	Processing date	O
T_PROCTIME	Processing time	O

- The simulator provides a wide range of possibilities to store information on transactions that accompany the transaction to the output data
- Can be used in analysing results ...
- ... and by user defined modules (e.g. new submission algorithms) to base their operation on

Transaction data (7)

... continued		
Field name	Detailed name	Required
T_ASSENAME	Asset name	O
T_DESCRIPT	Description	O
T_LINKCODE	Link code	O
T_LINKSYST	Linked system	O
T_TRANCLAS	Transaction class	O
T_USERDEID	User defined ID	O
T_USERCOD1...5	User defined codes 1...5	O
T_PRIORITY	Priority	O
T_PROCTYPE	Processing type	O
T_PROCDATE	Processing date	O
T_PROCTIME	Processing time	O

- Finally, the simulator offer the possibility to introduce various delayed processing options for transactions at a reference date/time
- The payment is submitted to the system, but settled only at date and time set here (either exactly at this time, not before this time, or it must be settled by this time)

Participant data (1)

Field name	Detailed name	Required
P_DATSETID	Data set ID	M
P_SYSTEMID	System ID	M
P_PARTICID	Participant ID	M
P_ACCOUNID	Account ID	M
P_FULLNAME	Full name	O
P_SHORTACR	Short acronym	O
P_ACCONAME	Account name	O
P_SETINSYS	Settles in system	O
P_SETONPAR	Settles on participant	O
P_SETONACC	Settles on account	O
P_LIQFRSYS	Liquidity injection from system	O
P_LIQFRPAR	Liquidity injection from participant	O
P_LIQFRACC	Liquidity injection from account	O
P_LIQINJVA	Participant/account specific liquidity injection value	O

System, participant and account information

- enables simulations for multiple systems (e.g. TARGET) and multiple accounts per participant (securities / FX settlement systems)

Participant data (2)

Field name	Detailed name	Required
P_DATSETID	Data set ID	M
P_SYSTEMID	System ID	M
P_PARTICID	Participant ID	M
P_ACCOUNID	Account ID	M
P_FULLNAME	Full name	O
P_SHORTACR	Short acronym	O
P_ACCONAME	Account name	O
P_SETINSYS	Settles in system	O
P_SETONPAR	Settles on participant	O
P_SETONACC	Settles on account	O
P_LIQFRSYS	Liquidity injection from system	O
P_LIQFRPAR	Liquidity injection from participant	O
P_LIQFRACC	Liquidity injection from account	O
P_LIQINJVA	Participant/account specific liquidity injection value	O

Information required for ancillary system settlement

- required for simulations where ancillary systems settle in a main system (e.g. Euro 1)

Participant data (3)

Field name	Detailed name	Required
P_DATSETID	Data set ID	M
P_SYSTEMID	System ID	M
P_PARTICID	Participant ID	M
P_ACCOUNID	Account ID	M
P_FULLNAME	Full name	O
P_SHORTACR	Short acronym	O
P_ACCONAME	Account name	O
P_SETINSYS	Settles in system	O
P_SETONPAR	Settles on participant	O
P_SETONACC	Settles on account	O
P_LIQFRSYS	Liquidity injection from system	O
P_LIQFRPAR	Liquidity injection from participant	O
P_LIQFRACC	Liquidity injection from account	O
P_LIQINJVA	Participant/account specific liquidity injection value	O

Information from which system and participant/account liquidity injections to the system are made

- required for the simulation of automatic liquidity bridges between two systems

Balance data

Field name	Detailed name	Required
B_DATSETID	Data set ID	M
B_SYSTEMID	System ID	M
B_PARTICID	Participant ID	M
B_DATEEFFE	Date effective	M
B_ACCOUNID	Account ID	M
B_NEWVALUE	New value	M

Identifiers as before

Balance at the beginning zero, set as changes

- Date when effective (from the beginning of the day)
- Account to which the balance is set
- New value of balance

Intraday credit data

Field name	Detailed name	Required
I_DATSETID	Data set ID	M
I_SYSTEMID	System ID	M
I_PARTICID	Participant ID	M
I_DATEEFFE	Date effective	M
I_TIMEEFFE	Time effective	M
I_ACCOUNID	Account ID	M
I_NEWVALUE	New value	M

Identifiers as before

As with balances before

However, a time must be set when the credit limit is changed (to enable intraday changes in credit limits)

Bilateral limits data

Field name	Detailed name	Required
L_DATSETID	Data set ID	M
L_FRSYSTID	System ID	M
L_FRPARTID	Participant ID	M
L_FRACCOID	Account ID	M
L_TOSYSTID	System ID	M
L_TOPARTID	Participant ID	M
L_TOACCOID	Account ID	M
L_DATEEFFE	Date effective	M
L_TIMEEFFE	Time effective	M
L_NEWVALUE	New value	M
L_DBCVALUE	Debit cap value	O
L-USERCOD1…5	User-defined codes 1…5	O

Identifyers and time labels as inintraday credit limits (ICCL)

Bilateral sending limit defined Bank A vis-a-vis bak B

Possible to use "multilimit" i.e. Bank A vis-a-vis all others

Reservations data

Field name	Detailed name	
R_DATSETID	Data set ID	M
R_SYSTEMID	System ID	M
R_PARTICID	Participant ID	M
R_ACCOUNID	Account ID	(M)
R_DATEEFFE	Date effective	M
R_TIMEEFFE	Time effective	M
R_NEWVALUE	New value	M
R_RESRVTYP	Reservation type	M
R-USERCOD1…5	Userdefined codes 1…5	O

- Table was included in DB structure in version 2.0.0 of BoF-PSS2
- General reservations features are to be implemented