EUROPEAN CENTRAL BANK

EUROSYSTEM

T2S CHANGE REQUEST FORM			
General Information (Origin of Request) ☐ User Requirements (URD) or GUI Business Functionality Document (BFD) ☒ Other User Functional or Technical Documentation (SYS)			
Request raised by: 4CB	**Institute:** 4CB		**Date raised:** 11/05/2021
Request title: T2S Multi-Criteria Settlement Optimisation			**Request No.:** T2S 0763 SYS
Request type: Common	**Classification:** Maintenance		**Urgency:** Normal
1. Legal/business importance parameter[1]: Medium		**2. Market implementation efforts parameter[2]:** Low	
3. Operational/Technical risk parameter[3]: Medium		**4. Financial impact parameter[4]:** (provided by 4CB)	
Requestor Category: 4CB		**Status:** Registered	

Reason for change and expected benefits/business motivation:

The general objective of T2S settlement optimisation procedures is to maximise the volume and value of settlement with the available securities and cash resources.
During the T2S project phase the market expressed some additional requirements regarding the settlement of transactions during the optimisation process.
These requirements can be summarized as follows:

1. T2S settlement optimisation engine shall favour the settlement of transactions with a higher level of priority
2. In case of the same level of priority competing for settlement, it shall favour the settlement of transactions with the oldest intended settlement date (ISD)
3. In case of the same level of priority and same intended settlement date, it shall favour the settlement of transactions in a way that maximises the volume and value of settlement (in an optimum balance)
4. It shall use resources for oldest transactions first in order to reduce the time during which a transaction remains unsettled beyond the intended settlement date

The requirements regarding priority and age could have been achieved using a hierarchical optimisation process. However, up to 2019 there was no optimisation solver at the state of the art allowing the design of T2S to achieve this hierarchical optimisation in an efficient manner. It has therefore been agreed during the design phase to handle these requirements in the Mathematical Optimisation Module using weights on pairs of priorities and ages and favour high priorities and/or ages by giving more weight to higher (priority, age).

Unfortunately, this weighting approach showed some weakness in the two last years as some issues were raised by the market regarding some priority and age not respected by the NTS settlement process.
These incidents have been closed vs the solution retained for the T2S design or handled with alternative solutions (e.gCR-741).

In the meantime, IBM Cplex the solver used in the Mathematical Optimisation Module has released a new feature in 2019 called “Multi-Objective” or “Multi-Criteria” allowing us to apply another solution approach and thus avoid the observed side-effects induced by the weighting approach. An evaluation of this new feature has shown that on tested cases where the weighting approach does not work the usage of this feature results to expected solution.

The aim of this change request is to apply this Multi-Criteria optimisation feature in the Mathematical Optimisation Module algorithms in order to improve the solution found by the optimisation process regarding priority and age requirement.

[1] Legal/business importance parameter was set to Medium because the background of this CR are production incidents, for which alternative solutions have been found in the meantime
[2] Market implementation effort parameter was set to Low because the change does not require a long implementation time and any significant resources on the side of Participating CSDs, CBs and their communities
[3] Operational/technical risk parameter was set to Medium because the CR will modify algorithms which are the core of the T2S settlement functionality.
[4] Low < 100kEUR < Low-Medium < 200 kEUR < Medium < 400kEUR < High < 700kEUR < Very high

Description of requested change:

Reminder: current weighted objective

T2S Night Time Settlement process

During the night-time settlement period, the T2S settlement is split into cycles and sequences defining the settlement process perimeter and scheduling.

- Sequence 0 : Liquidity transfers and cash settlement restrictions;
- Sequence 1 : Settlement instructions related to corporate actions;
- Sequence 2 : Free of Payment (FOP) Settlement instructions for rebalancing purpose;
- Sequence 3 : Settlement instructions related to Central Bank Operations (CBO);
- Sequence 4: All type of settlement instructions, settlement restrictions and liquidity transfers;
- Sequence X: Sequence 4 with partial settlement available;
- Sequence Y: Liquidity transfers related to reimbursement of the "multiple liquidity providers";
- Sequence Z: All liquidity transfers.

Current scheduling of night-time is:

- Cycle 1: Sequence 0, Sequence 1, Sequence 2, Sequence 3 and Sequence 4;
- Last cycle: Sequence 4, Sequence X, Sequence Y and Sequence Z.

The Mathematical Optimisation Module

The Mathematical Optimisation Module[5] runs in sequences 1 to X with a series of settlement optimisation algorithms associated to the current cycle-sequence. Each algorithm tries to find the "best" (i.e. with the highest value of its objective function) set of transactions based on its own optimisation strategy and is executed in sequence to improve the previous settlement ratio of the previous cycle-sequence in a predefined time constraint.

Series of settlement optimisation algorithms are basically composed by three steps:

1. A building step: mathematical optimisation algorithms using IBM Cplex helps to select rapidly a subset of Settlement Transactions which may be part of a good solution;
2. An improvement step: algorithms based on local search theory aim to enhance the previous solution;
3. A reparation step: ad hoc algorithm applies all T2S Business Rules to transform previous "temporary" solution to a final solution (i.e. a settlable collection of Settlement Transactions). Some of those reparation algorithms are using IBM Cplex.

Each step of the optimisation algorithms is guided by its own implementation of the optimisation objective function to find the best reachable solution.

The optimisation function calculate a Balanced Ratio Indicator (BRI). The BRI is today expressed as a linear objective function with different weights for the different level of priority p and age a with ages capped to 3.

$$BRI_\lambda = \frac{1}{\sum_{p,a} Weight(p,a)} \sum_{p,a} Weight(p,a) \times BRI_\lambda(p,a)$$

Where the BRI(p,a) is the balance between volume and value ratio respectively Rvol and Rval

$$BRI_\lambda(p,a) = \lambda R_{Vol}(p,a) + (1-\lambda) R_{Val}(p,a)$$

[5] The Night-Time Settlement (NTS) functional design is described in 'UDFS- T2S NTS Algorithms Objectives'.
More information about the Mathematical Optimisation Module can be found in the scientific paper "Securities and cash settlement framework" in International Conference on Mathematical Optimization Theory and Operations Research (E. Alekseeva et al. ,2020).

In T2S, since the go-live, the lambda value is set to 0.5.

The weights are obtained with the following formula

$$Weight(p,a) = \frac{1}{10^{2(4p-a-1)}}$$

This formula should have ensured a sufficient gap between weights for higher and lower (priority, age). Unfortunately, this does not work in all situations and may end up with transaction with lower priority settled instead of higher priority.

Proposed change: multi-criteria objective

4CB proposes to replace the weighted objective function in the algorithms implemented with IBM Cplex by a hierarchical multiple objectives, these modifications affect three main algorithms: two building algorithms and one reparation/improvement algorithm.

Below a simplified representation of the proposed changes:

Current implementation

Maximize

$$BRI_\lambda = \frac{1}{\sum_{p,a} Weight(p,a)} \sum_{p,a} Weight(p,a) \times BRI_\lambda(p,a)$$

Where

$$BRI_\lambda(p,a) = \lambda R_{Vol}(p,a) + (1-\lambda) R_{Val}(p,a)$$

(p,a) in				
	(Reserved,3)	(Top,3)	(High,3)	(Normal,3)
	(Reserved,2)	(Top,2)	(High,2)	(Normal,2)
	(Reserved,1)	(Top,1)	(High,1)	(Normal,1)
	(Reserved,0)	(Top,0)	(High,0)	(Normal,0)

New implementation

Maximize **multi-objectives**

(Reserved, 3) : BRI_λ (Reserved, 3)

(Reserved,2) : BRI_λ (Reserved, 2)

….

(Top,3) : BRI_λ (Top, 3)

….

(Normal, 0) : BRI_λ (Normal, 0)

Where

$$BRI_\lambda(p,a) = \lambda R_{Vol}(p,a) + (1-\lambda) R_{Val}(p,a)$$

Under the new implementation, for any (priority, age) level an optimisation attempt is executed taking into account all transactions from higher, current and lower (priority, age) levels and the solution obtained from the previous optimisation attempt illustrated as follows:

- The first optimization attempt involves all transactions but maximize only BRI_lambda(reserved,3)
  The solution found after this attempt is the optimal solution for (reserved,3) with BRI_lambda (reserved, 3) = Opt_R3.

- The objective of the second optimization is to maximize BRI_lambda (reserved,2)
  It involves all transactions with a constraint on
  - BRI lambda (reserved,3) >= Opt_R3

  The optimal solution found has BRI_lambda (reserved,2) = Opt_R2 and the solution for transactions R3 remains optimal.

- The objective of the third optimization is to maximize BRI_lambda (reserved,1)
  It involves all transaction with a constraint on
  - BRI_lambda(reserved,3) >= Opt_R3
  - BRI_lambda(reserved,2) >= Opt_R2

  The optimal solution found has BRI_lambda (reserved,1) = Opt_R1 and the solution for transactions R2 and higher remains optimal

- The objective of the fourth optimization is to maximize BRI_lambda (reserved,0)
  It involves all transactions with a constraints on
  - BRI_lambda(reserved,3) >= Opt_R3
  - BRI_lambda(reserved,2) >= Opt_R2
  - BRI_lambda(reserved,1) >= Opt_R1

- The optimal solution found has BRI_lambda (reserved,0) = Opt_R0 and the solution for transactions R1 and higher remains optimal.

- The objective of the fifth optimization is maximize BRI_lambda (top, 3)
  It involves all transactions with a constraint on
  - BRI_lambda(reserved,3) >= Opt_R3
  - BRI_lambda(reserved,2) >= Opt_R2
  - BRI_lambda(reserved,1) >= Opt_R1
  - BRI_lambda(reserved,0) >= Opt_R0

  The optimal solution found has BRI_lambda (top, 3) = Opt_T3 and the solution for transactions R0 and higher remains optimal.

- The objective of the sixth optimization is to maximize BRI_lambda (top, 2)
  It involves all transactions with a constraint on
  - BRI_lambda(reserved,3) >= Opt_R3
  - BRI_lambda(reserved,2) >= Opt_R2
  - BRI_lambda(reserved,1) >= Opt_R1
  - BRI_lambda(reserved,0) >= Opt_R0
  - BRI_lambda(top, 3) >= Opt_T3

  The optimal solution found has BRI_lambda (top, 2) = Opt_T2 and the solution for transactions T3 and higher remains optimal.

  Etc…

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This new implementation:

- will be introduced at least in cycle-sequences 4 and X whereas the preceding cycle-sequences are less subject to the described weakness of the weighting approach because the optimisation problem to solve is easier (less transactions competing for the same resources).

- will require performance tests in a wide range of production data benchmarks in order to assess the impact on the whole framework execution time and efficiency. According to the tests results it may be necessary to find a trade-off between the hierarchical multiple objectives and the weighted objectives and/or to keep, for example, the reparation algorithm unchanged while preserving the improvement achieved by this new implementation with the other algorithms.

Submitted annexes / related documents:

Outcome/Decisions:

*CRG on 25 May 2021 : the CRG agreed to launch the preliminary assessment of CR-763.

Documentation to be updated:

Preliminary assessment:

Detailed assessment: