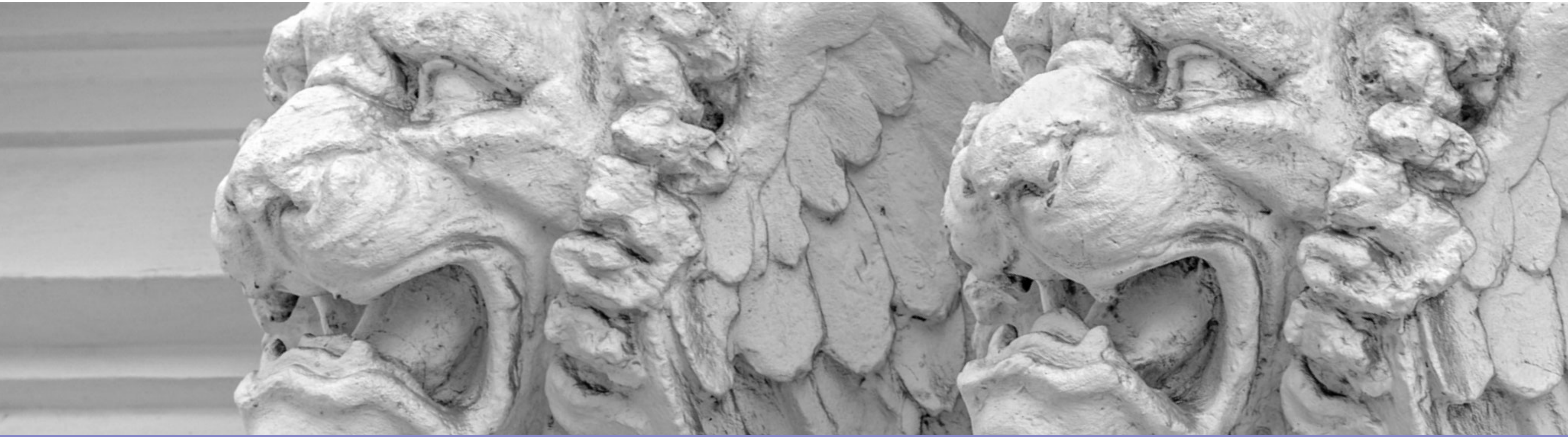
Bank of Russia

The Central Bank of the Russian Federation



Strong Liquidity Saving Features in the Payment System design

Efficient liquidity saving mechanism and gridlock resolution procedures in RTGS systems

Vladimir Kulipanov,

Economical adviser,

National payment system Department,

August 30, 2018

Helsinki,

BOF16th Simulator Seminar

What is the problem

Despite the fact that RTGS systems can effectively eliminate the credit exposure between the paying bank and the receiving bank at the interbank level by means of fast final and irrevocable money transfer, there is another serious problem associated with these systems.

What is the problem

Despite the fact that RTGS systems can effectively eliminate the credit exposure between the paying bank and the receiving bank at the interbank level by means of fast final and irrevocable money transfer, there is another serious problem associated with these systems.

Liquidity Demand in Net Settlement Systems

RTGS systems turned out to be liquidity-demanding arrangements, as opposed to net settlement systems.

Liquidity Demand in Gross Settlement Systems

CBR experience of the year 1998

Facts of August 1998

- Central Bank has low international reserves;
- Unfavorable commodity prices for the Russian export products;
- Aggressive government borrowing at domestic market;

Events of August 1998

- Government default on the State Short-Term Bonds;
- Sharp increase of the CBR lending and borrowing rate up to 150%;
- Subsequent failure of several banks;
- The freezing of interbank market;
- Liquidity shortage in the banking system;
- Massive gridlocks in the payment system, resulting in painful payment cancellations of at EOD.

Why does liquidity has to be efficiently managed in RTGS

The efficiency of liquidity management arrangements is the precondition of smooth RTGS operation (especially in tough times when liquidity is a systemic shortage).

If liquidity management is inefficient, the RTGS may stop operating properly by terminating in the grid-lock state brining chaos to the national economy.

The functionality of Liquidity-Saving features in modern RTGS systems is based on the central queue, where the incoming payment instructions are stored in anticipation of settlement.

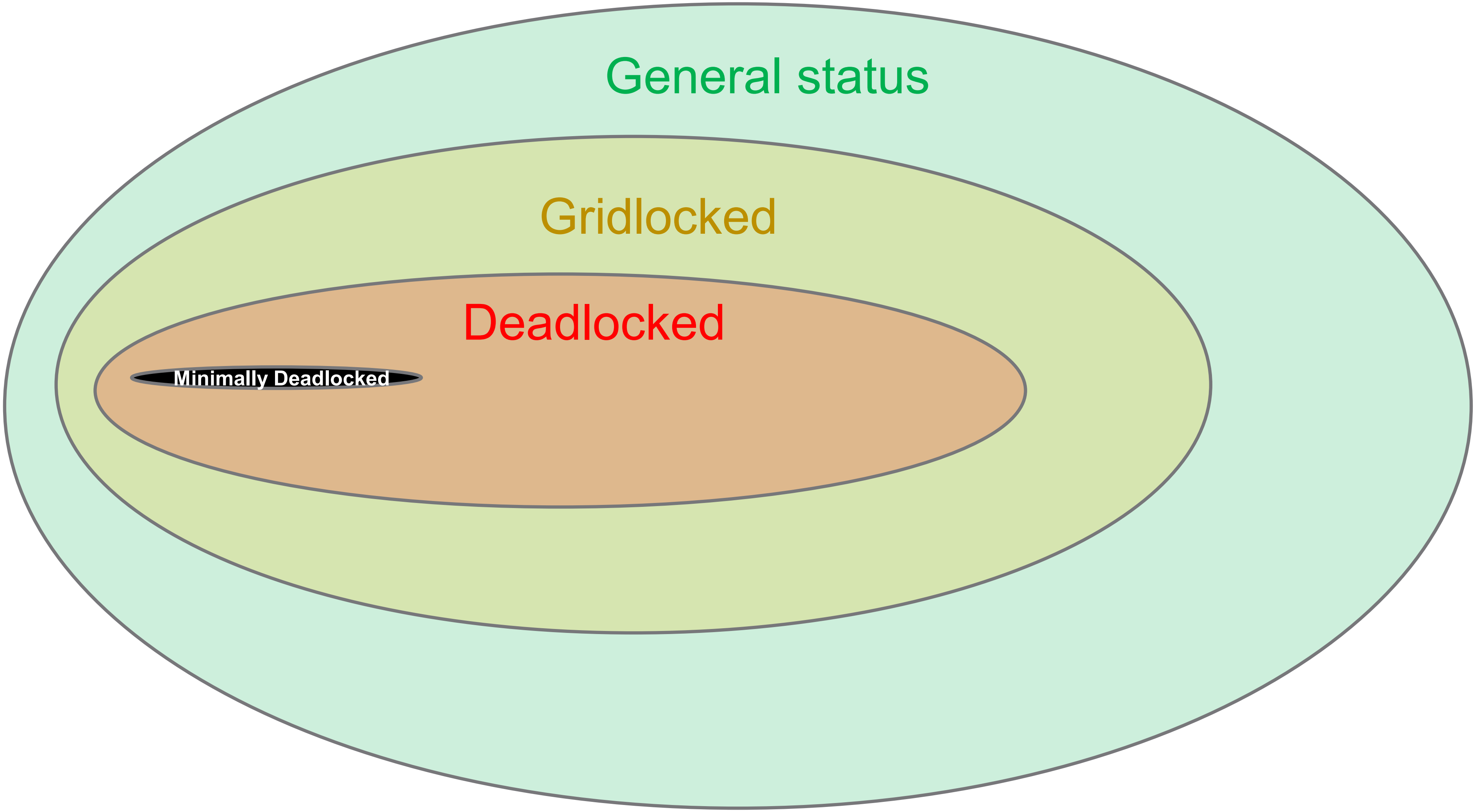
You may think of the central queue as a simple collection of payment instructions (PI_k).
Often (but not always) the payment instructions in the central queue have certain “wealth” function (W) defined on their value, and/or the input time. If defined, this function is used primarily to create the sequential order of payments over the central queue.

$$Central\ queue = \{PI_k\}, k = \overline{1, n};$$

The Liquidity-Saving feature is the function that enables RTGS system to transform the central queue from the general status to some alternative reduced status without noticeable liquidity burden.

The efficiency of this reduction is determined by class of the destination status of the central queue.

Status of the central queue

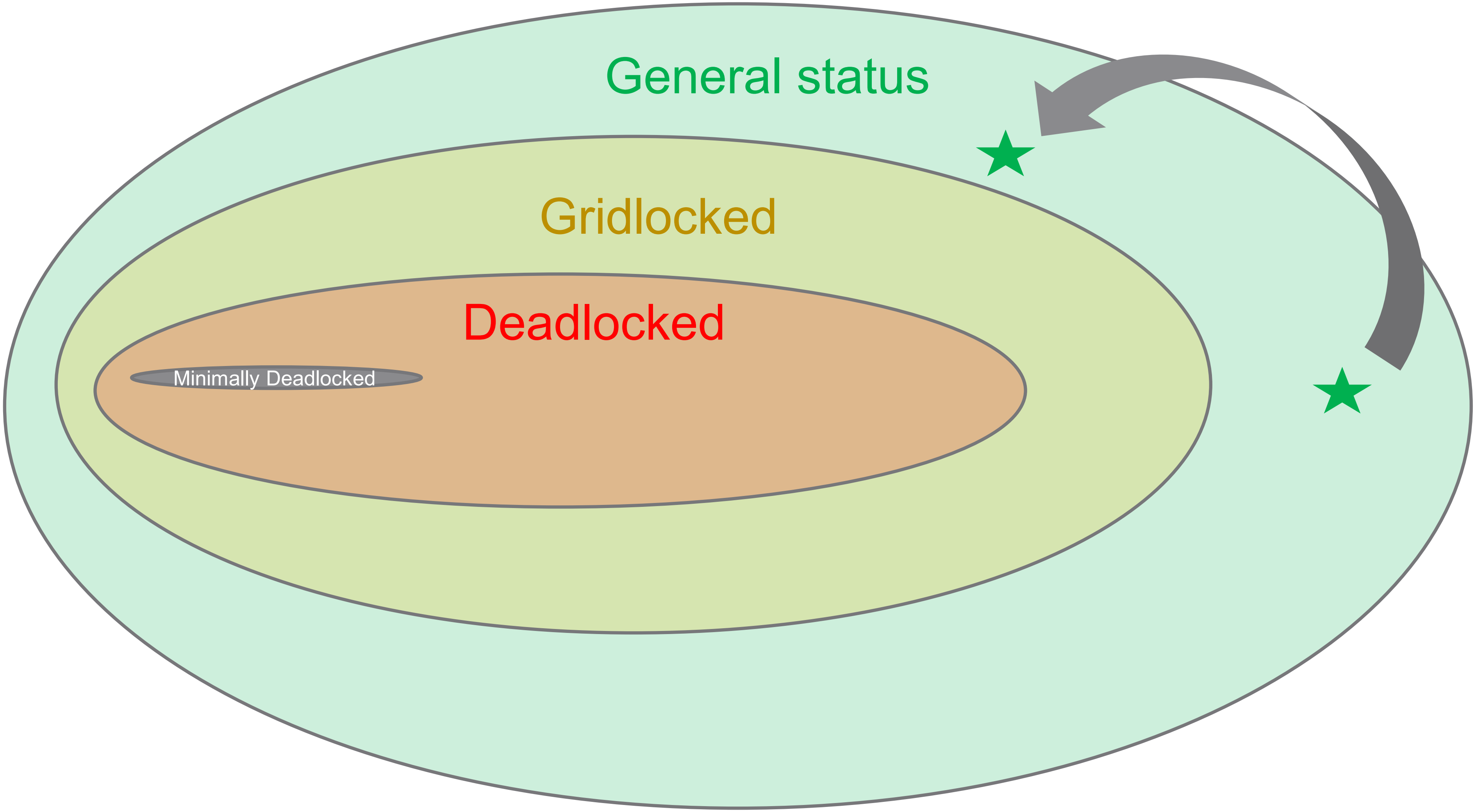


Status of the central queue

№	Status	Description
1	General	Any queue that may be encountered in a payment system during it's operation.
2	Gridlocked	When no collection of payments can be settled under FIFO and priorities restrictions.
3	Deadlocked	When no collection of payments can be settled. ~~under FIFO and priorities restrictions~~
4	Minimally Deadlocked	The deadlocked queue with minimal aggregate value of payments across all deadlocked queues, to which the initial general status can be reduced.

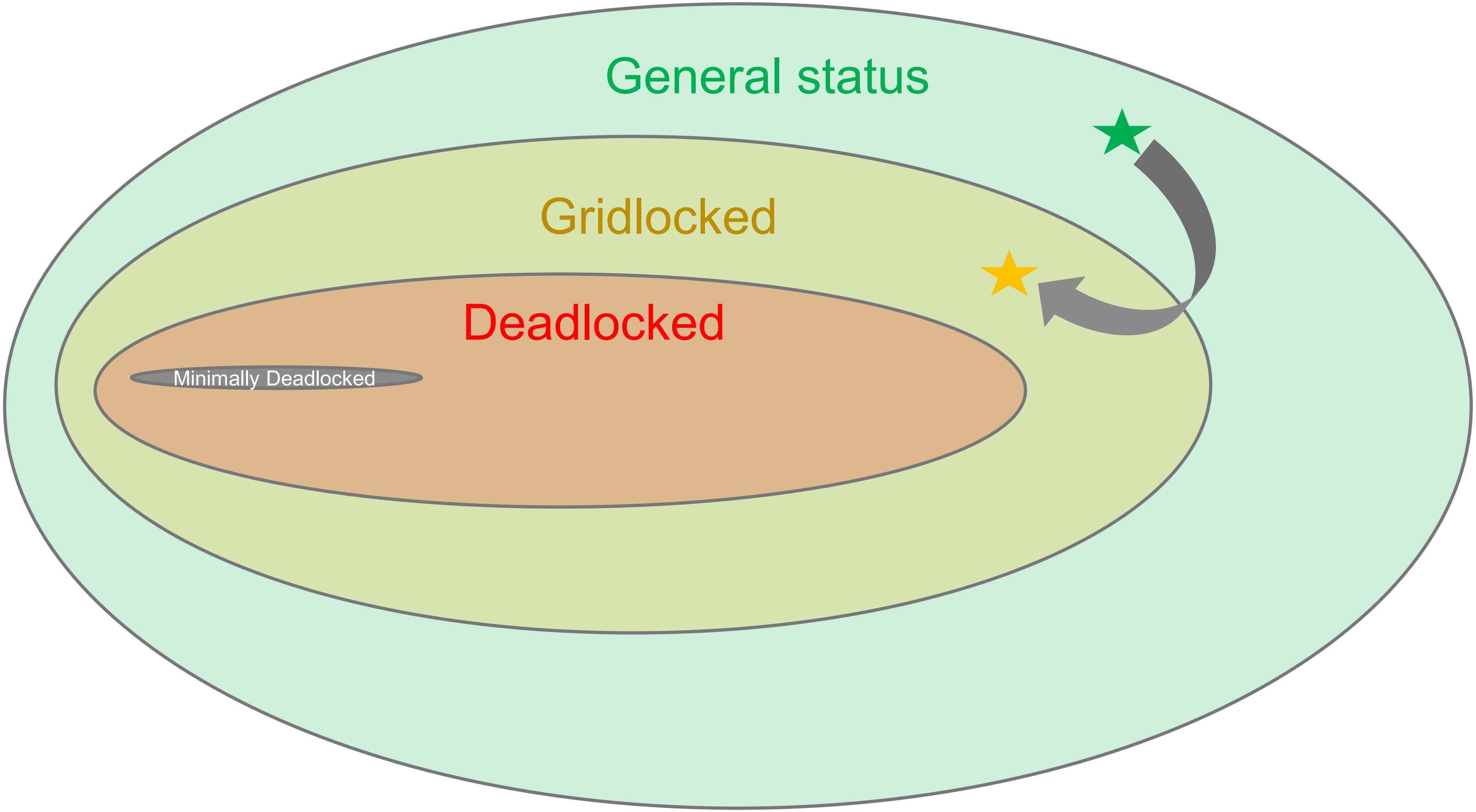
Reductions over the central queue

- Bilateral offsetting

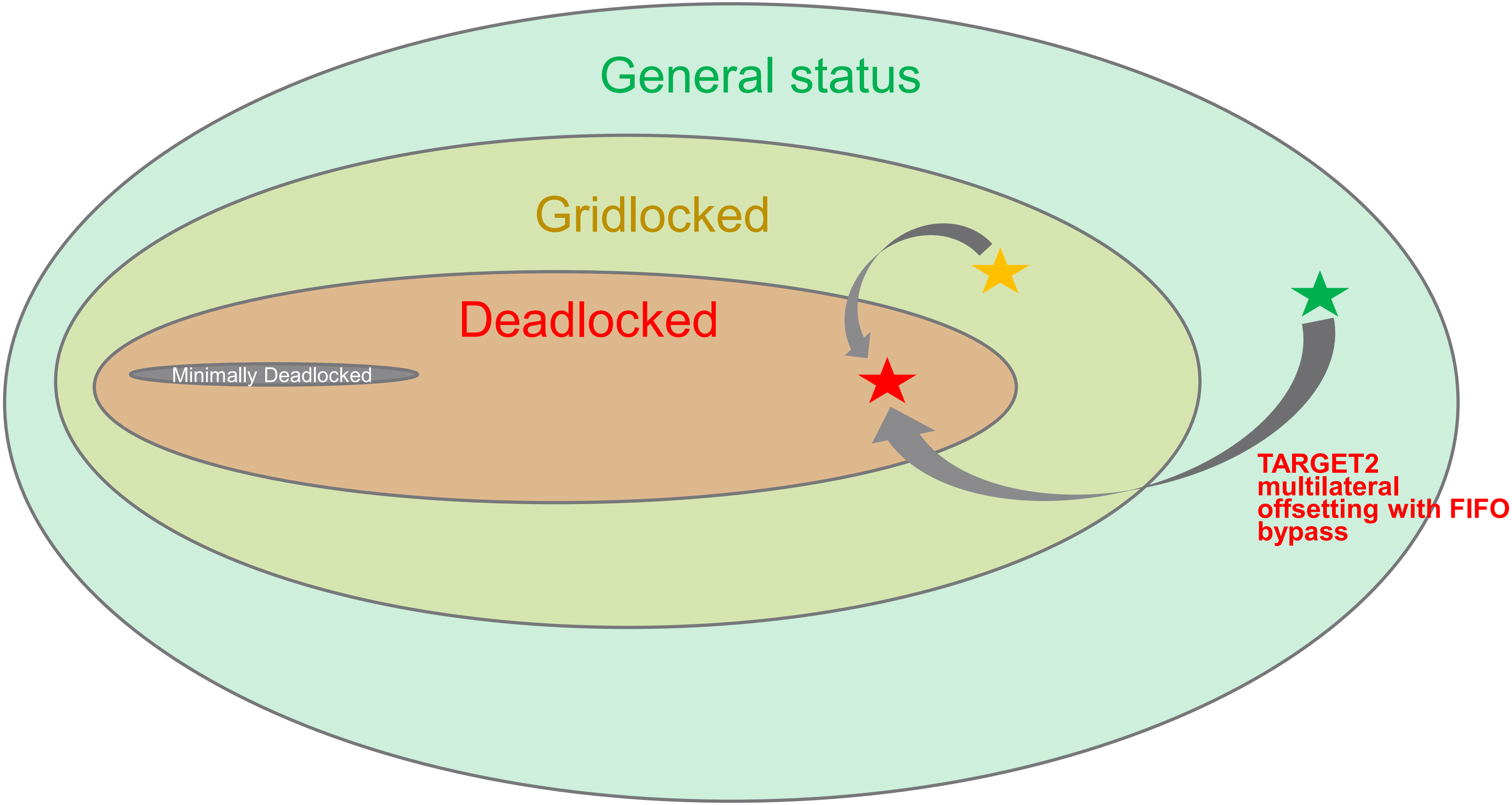


Reductions over the central queue

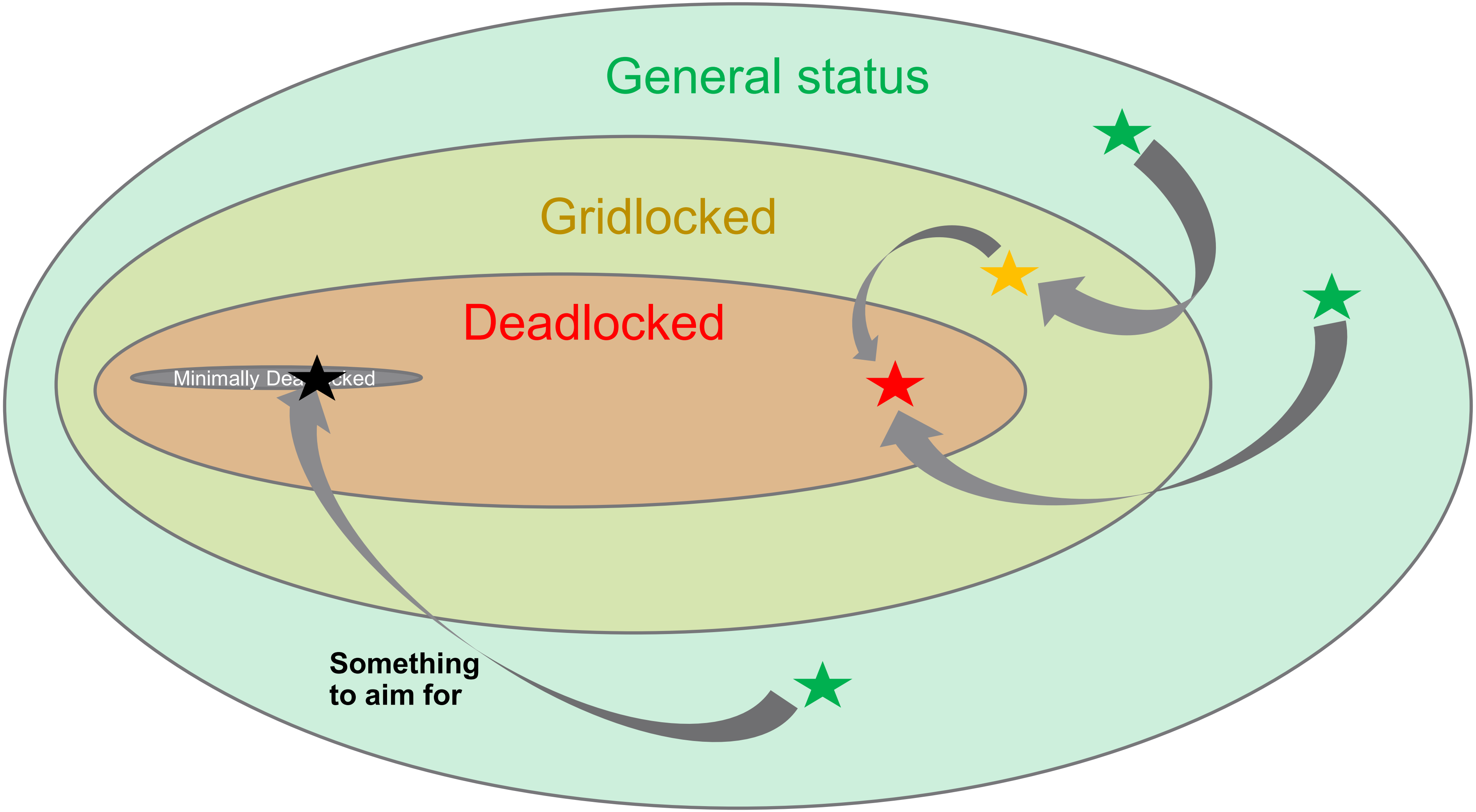
- Morten Bech & Kimmo Soramaki;



Reductions over the central queue



Reductions over the central queue



Bank of Russia
The Central Bank of the Russian Federation

Mathematical formalism

Formalism for the Bank clearing problem

$$\begin{cases} 0 \le x_{ijk} \\ 0 \le \xi_{ijk} \\ 0 \le \zeta_i \\ x_{ijk} + \xi_{ijk} = 1 \\ \sum_{jk} a_{ijk} * x_{ijk} - \sum_{pq} a_{piq} * x_{piq} + \zeta_i = B_i \end{cases}$$

$$x_{ijk} - integer$$

$$F \rightarrow max$$

$$F = \sum_{ijk} a_{ijk} * x_{ijk}$$

This problem belongs to knapsack-packing sub-class of integer linear programming (ILP).
It is known to be NP-hard.

Linear program relaxation

$$
\begin{cases}
0 \leq x_{ijk} \\
0 \leq \xi_{ijk} \\
0 \leq \zeta_i \\
x_{ijk} + \xi_{ijk} = 1 \\
\sum_{jk} a_{ijk} * x_{ijk} - \sum_{pq} a_{piq} * x_{piq} + \zeta_i = B_i
\end{cases}
$$

~~x_{ijk} – integer~~ *

$$F \rightarrow max$$

$$F = \sum_{ijk} a_{ijk} * x_{ijk}$$

*Instead of solving the problem we **should** solve, we would solve the problem we **can** solve.

Dual Linear Problem (LP)

||A||x=B
Fx->max

$||A||^T$y=F
By->min

The dual linear problems
for the real-world instances of the Bank Clearing Problem
are much easier (faster) to solve, compared to direct LP.

What is the duality about?

The direct linear problem for BCP

Start from the point where **none** of the payments **are settled**.
Try to settle **as much** value in payments **as possible** while maintaining the account balances positive.

What is the duality about?

The direct linear problem for BCP

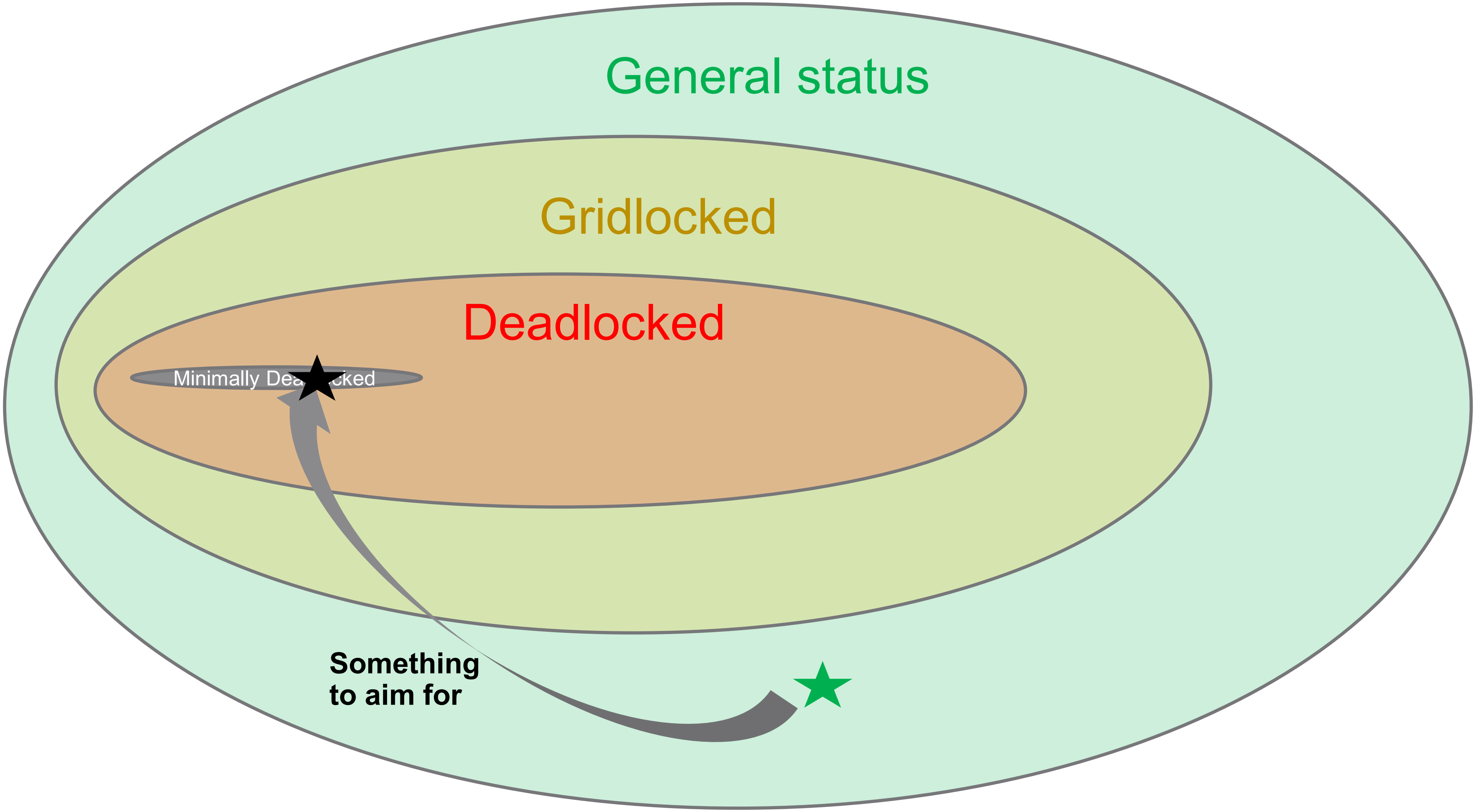
Start from the point where **none** of the payments **are settled**.
Try to settle **as much** value in payments **as possible** while maintaining the account balances positive.

The dual linear problem for BCP

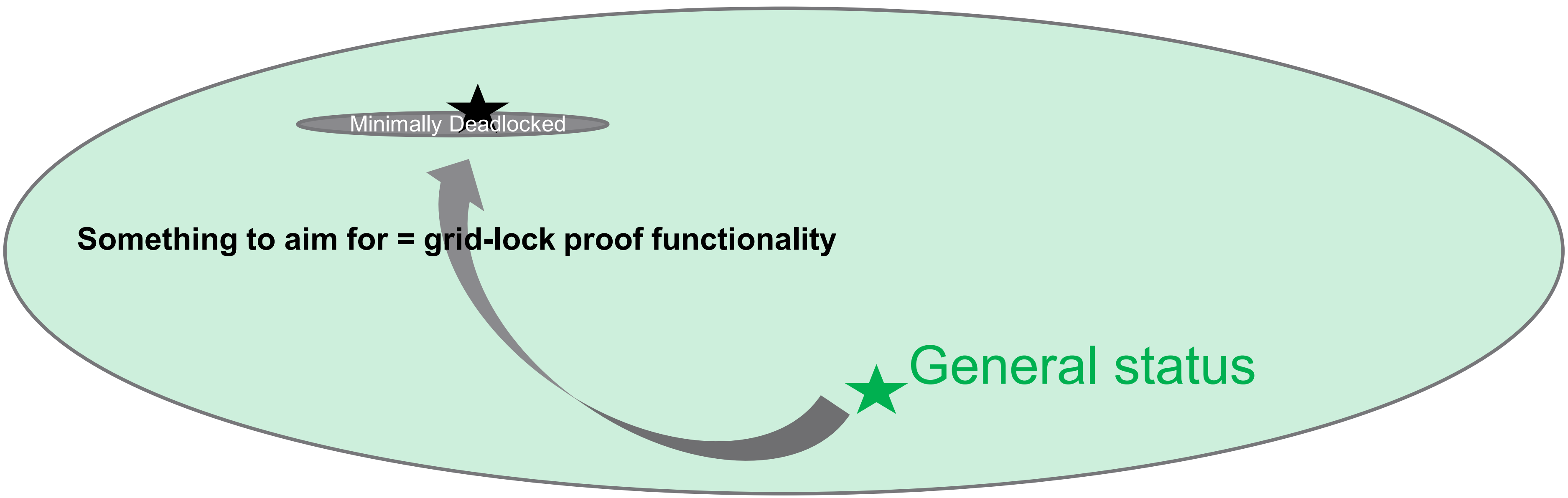
Start from the point where **every** payment **is settled**.

Try to bring the account balances to consistent state (to non-negative balances) while rejecting **as less** value in payments **as inevitable**.

RTGS with liquidity-saving functionality of this kind achieves the desired reduction



These are grid-lock proof RTGS



MaxFlow-MinCost interpretation of the Dual Liner Problem

Let’s define the network as the collection of the accounts.

We shall assign emitting capacity to the accounts with negative positions.

We shall assign absorbing capacity to the accounts with positive positions.

We shall assign non-zero capacity to every ordered pair of the accounts,
if there is at least one payment from the first account to the second account.
Zero direct capacity will be assigned to every ordered pair of the accounts,
if there is no one payment from the first account to the second account.

MaxFlow-MinCost interpretation of the Dual Liner Problem

We define the intensity of the flow as the sum of all emission.

We define the price of the flow as the sum of all used capacities.

MaxFlow-MinCost interpretation of the Dual Liner Problem

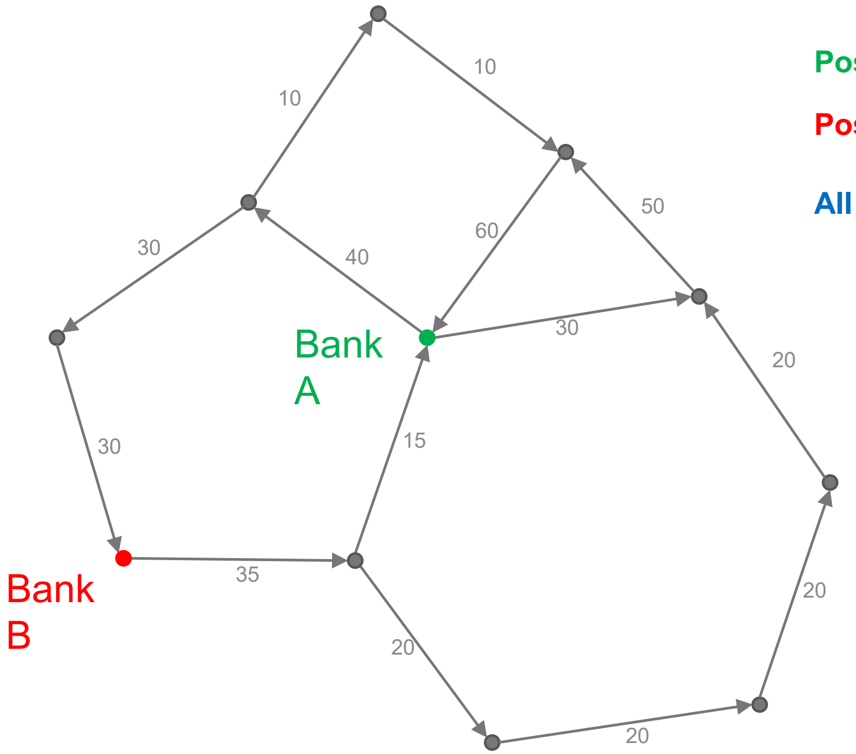
The flow that meets the emission, absorption and capacity restrictions, is deemed feasible.

MaxFlow-MinCost interpretation of the Dual Liner Problem

The feasible flow of the least possible price defines the solution of the Dual Linear Problem.

Illustrative example

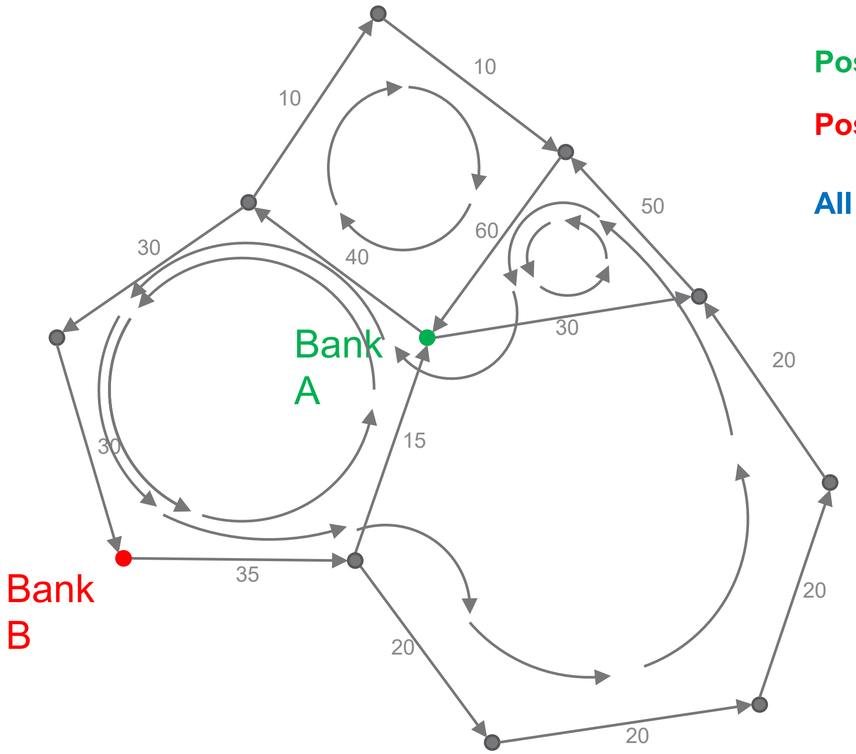
Decomposition any network flow into Circulation and MaxFlow-MinCost



Position(A)=+5

Position(B)=-5

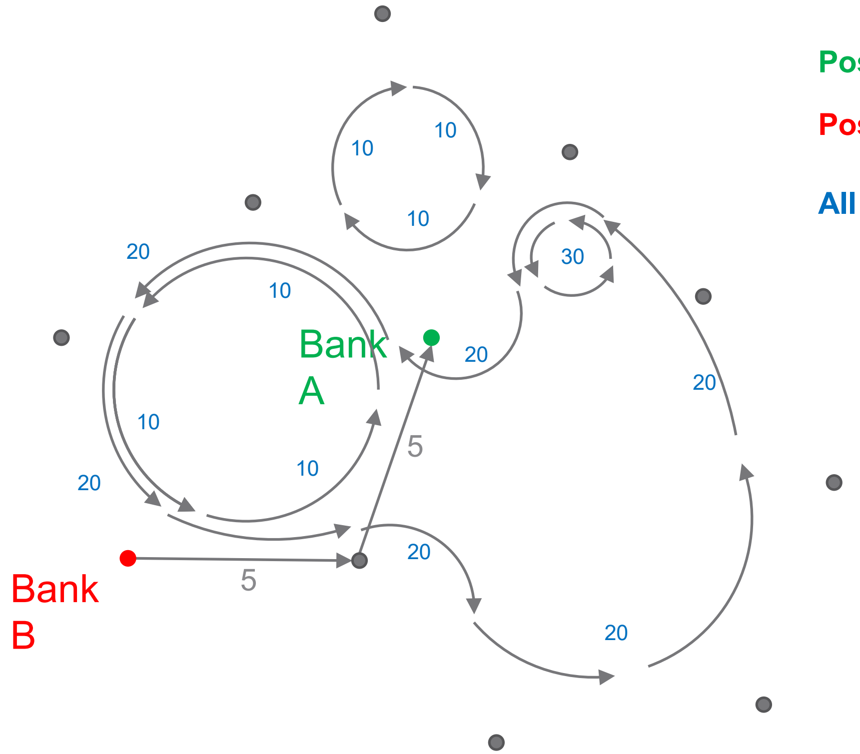
All other positions=0



Position(A)=+5

Position(B)=-5

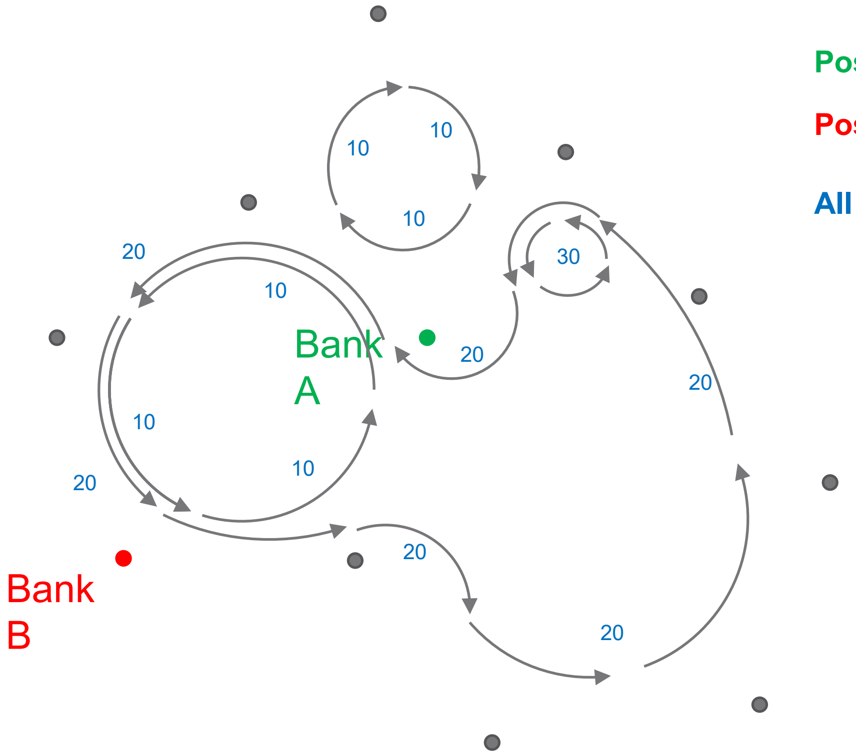
All other positions=0



Position(A)=+5

Position(B)=-5

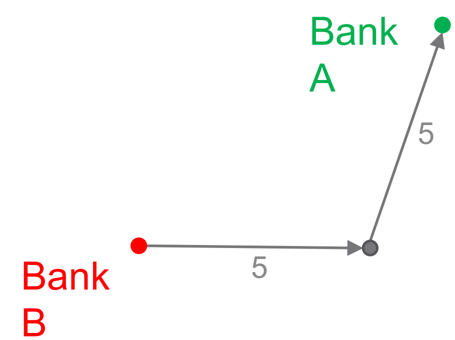
All other positions=0

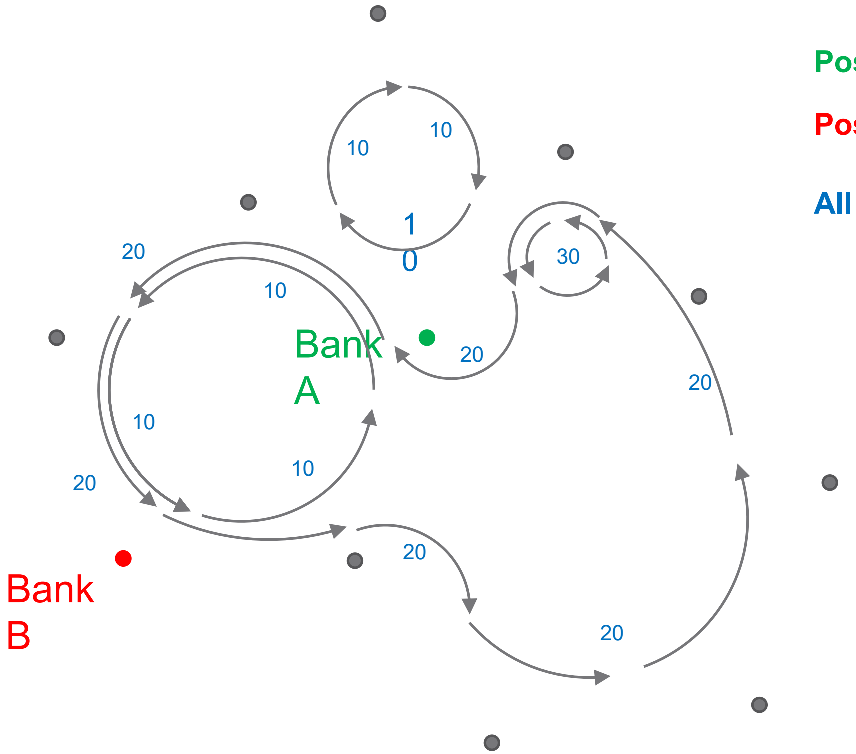


Position(A)=+5

Position(B)=-5

All other positions=0

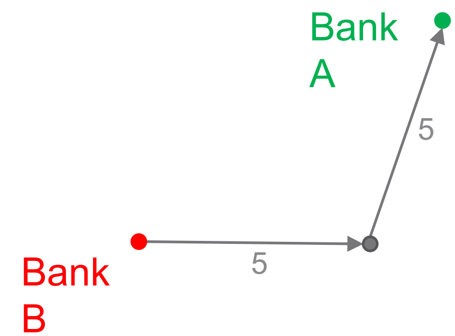




Position(A)=+5

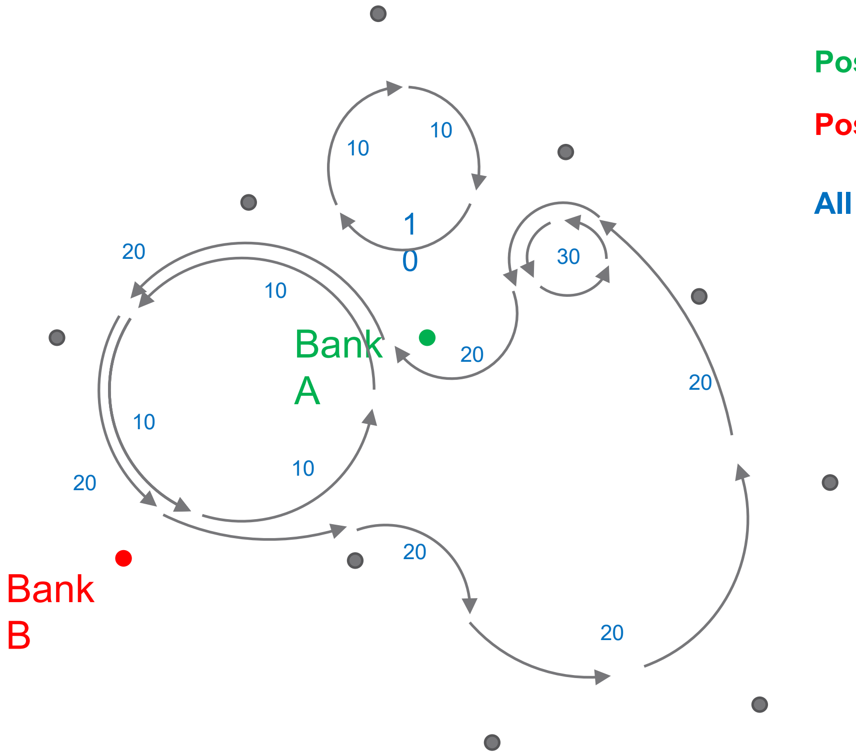
Position(B)=-5

All other positions=0



Circulation:
Zero Intensity, Max Cost

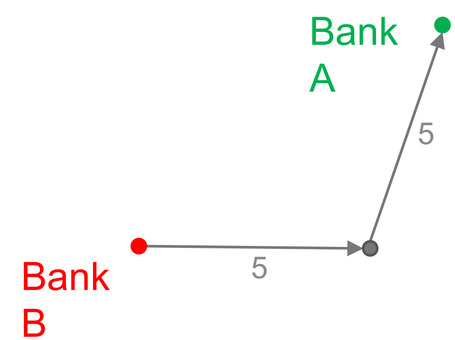
MaxFlowMinCost:
Maximum Intensity, Minimal Cost



Position(A)=+5

Position(B)=-5

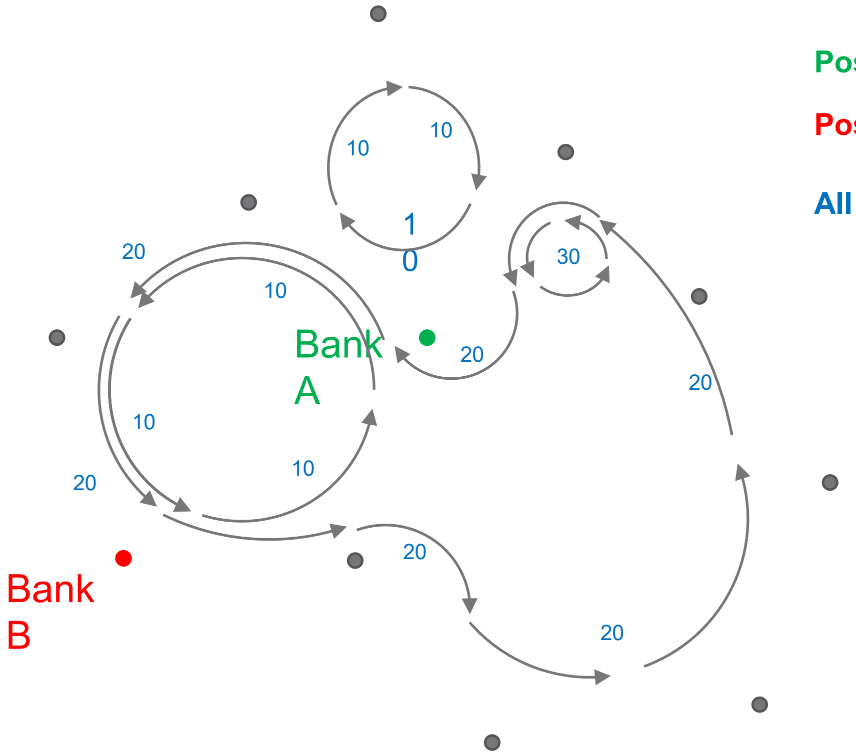
All other positions=0



No funds are required for settlement

Circulation:
Zero Intensity, Max Cost

MaxFlowMinCost:
Maximum Intensity, Minimal Cost

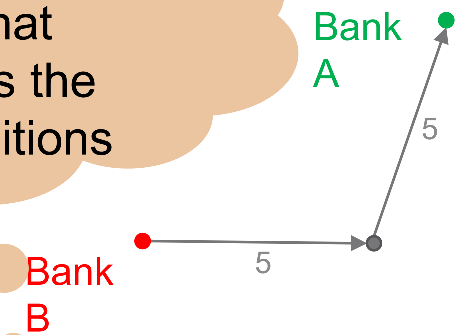


Position(A)=+5

Position(B)=-5

All other positions=0

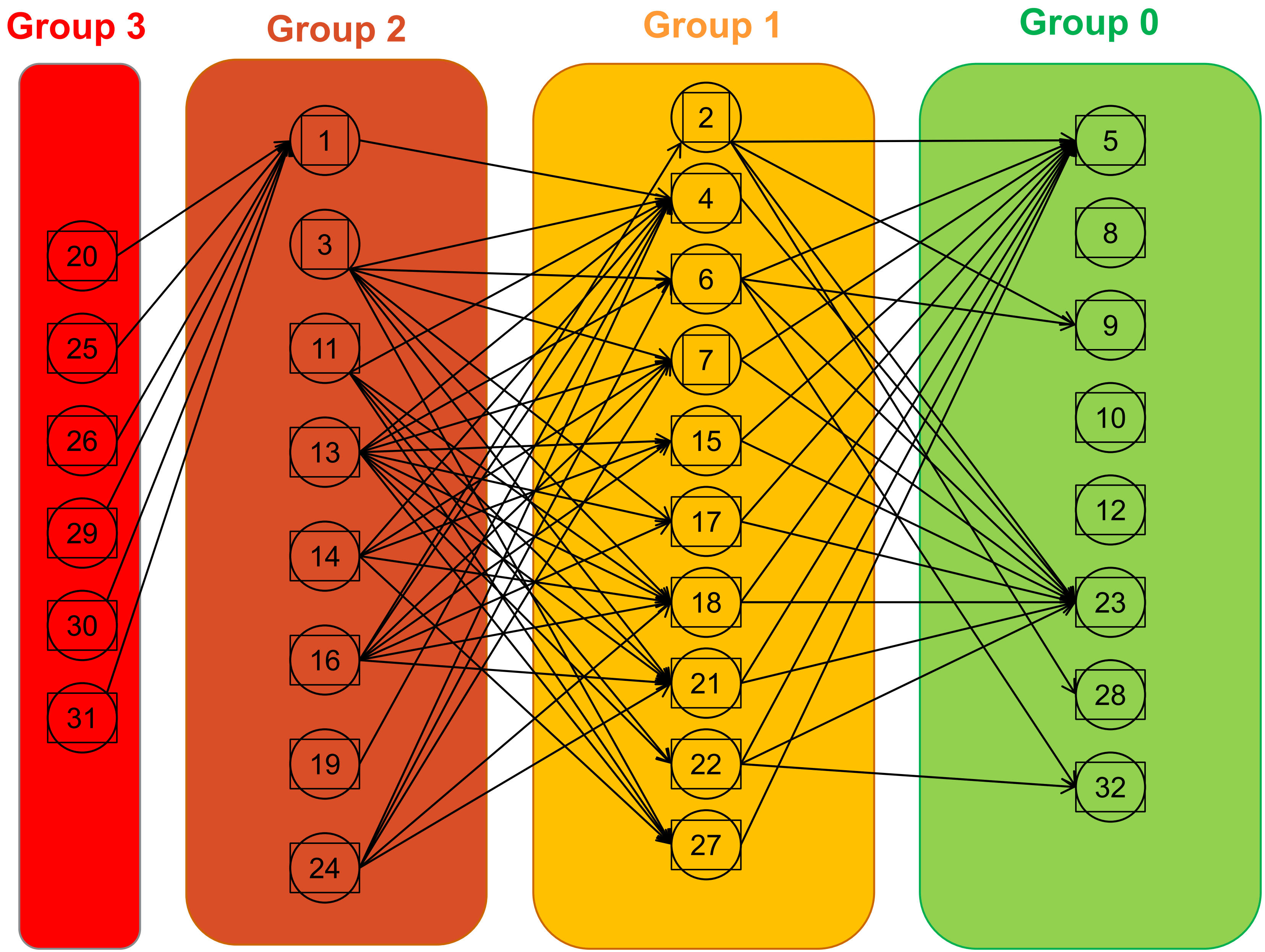
The minimal-cost flow, that produces the initial positions



No funds are required for settlement

Circulation:
Zero Intensity, Max Cost

MaxFlowMinCost:
Maximum Intensity, Minimal Cost


Group 3
Group 2
Group 1
Group 0
20
25
26
29
30
31
1
3
11
13
14
16
19
24
2
4
6
7
15
17
18
21
22
27
5
8
9
10
12
23
28
32

Analytical properties of the above graphical tool

Immediately diagnosed the severity of economical conditions

Illustrate the real net flow of funds in the banking system

Provide correct and efficient prescriptions for Central bank liquidity interventions

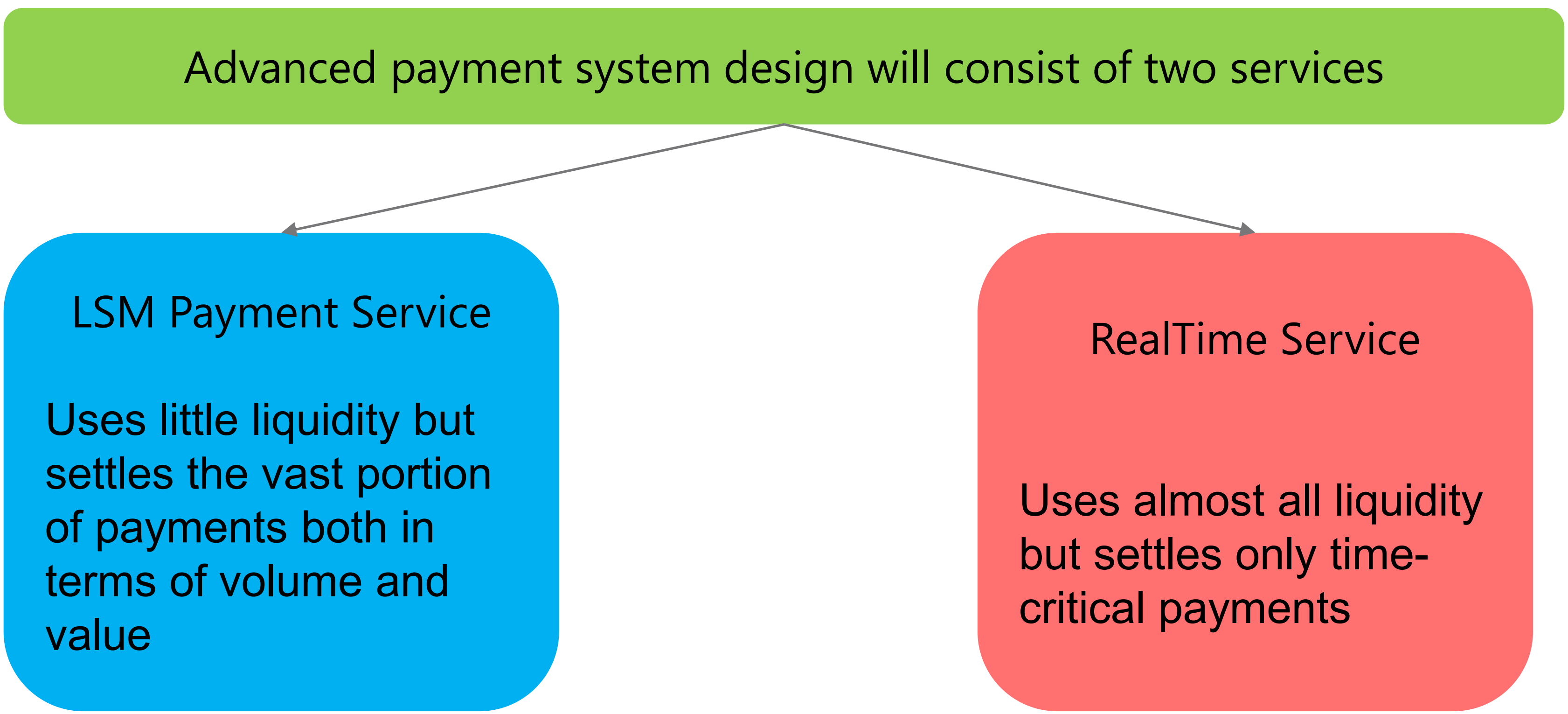
Contribute to find the feasible integer solution to the BCP, in the neighborhood of the optimal solution to Linear Program

Policy implications

Payment System Policy Implications

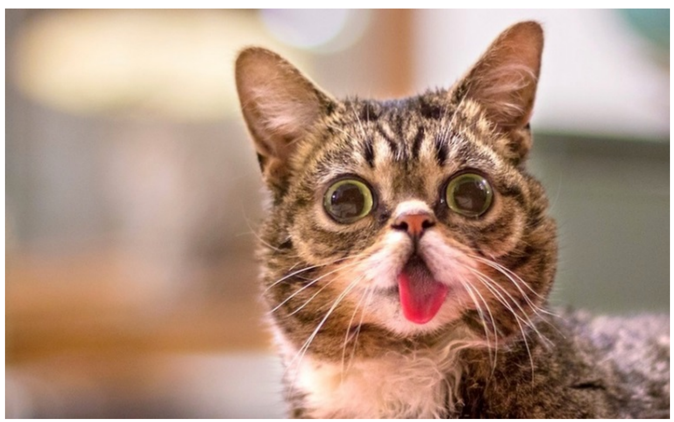
- The suitable design of the payment system (two distinct services: LSM service and RealTime service)
- Is money really required for settlement to take place?
- In liquidity saving strategy of PS participant, the value of the payment does not matter. What matters, is the direction of the payment.
- Free riding strategy and Incentives for the participant’s behavior;
- The dependency of the settlement results on the value of the available liquidity;
- Central bank liquidity interventions;
- The consequences of unwinding;
- Fairness concept suggested by Bech & Soramaki;
- Maintaining the collateral at minimum;

The suitable design of the payment system (two distinct services: LSM service and RealTime service)



Is money really required for settlement to take place?

No money is required in LSM Service



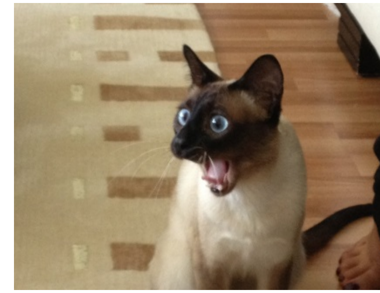
What is more important in liquidity-saving strategy of the payment system Participant

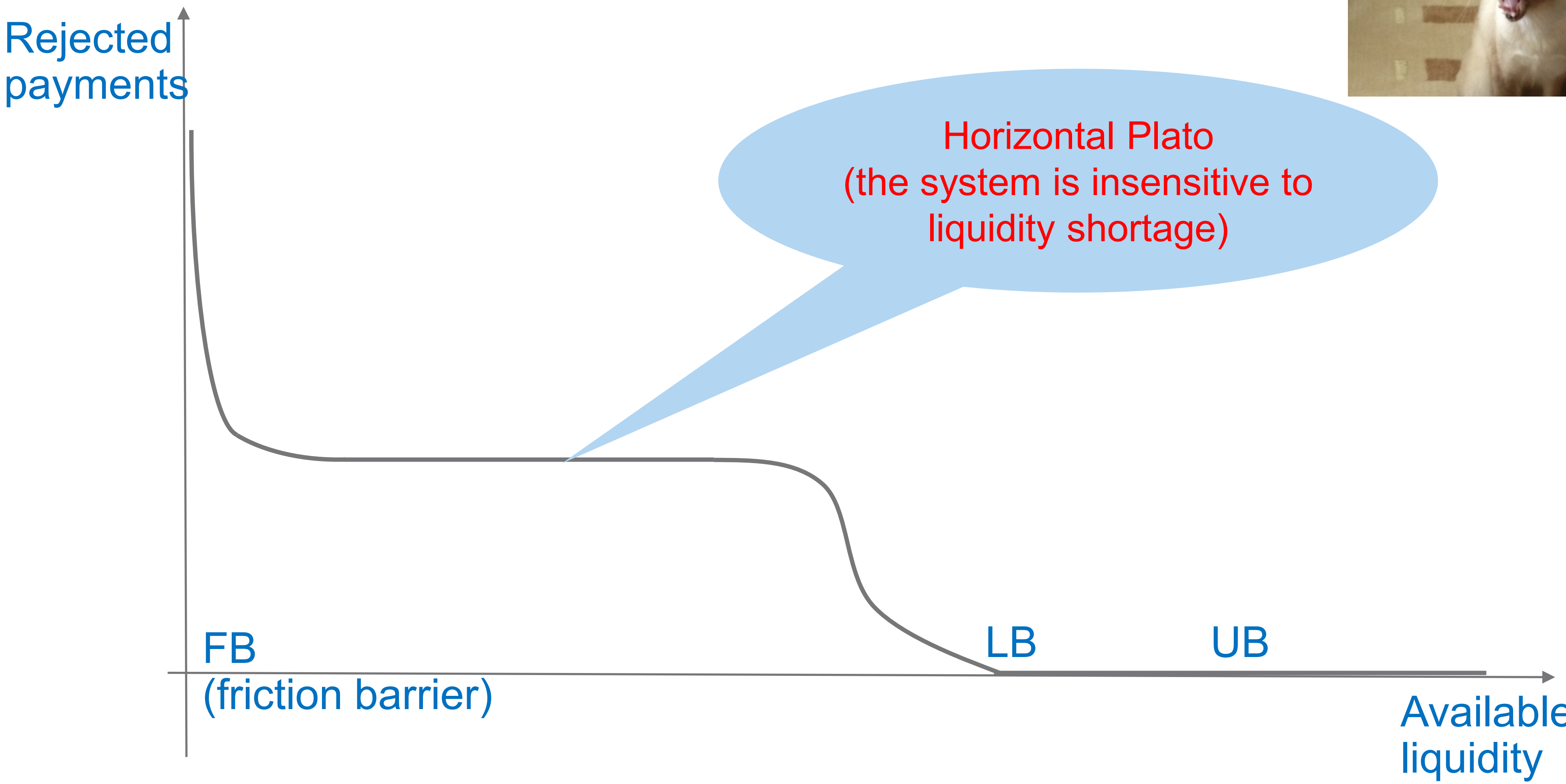
The value of the payment does not matter. What matters, is the direction of the payment.

Free-Riding strategy and Incentives for the participant’s behavior

In Liquidity-Saving Service, the Free-Riding strategy is something that is supported by the definition. And it turns out to be the most welcome and mutually beneficial behavior.

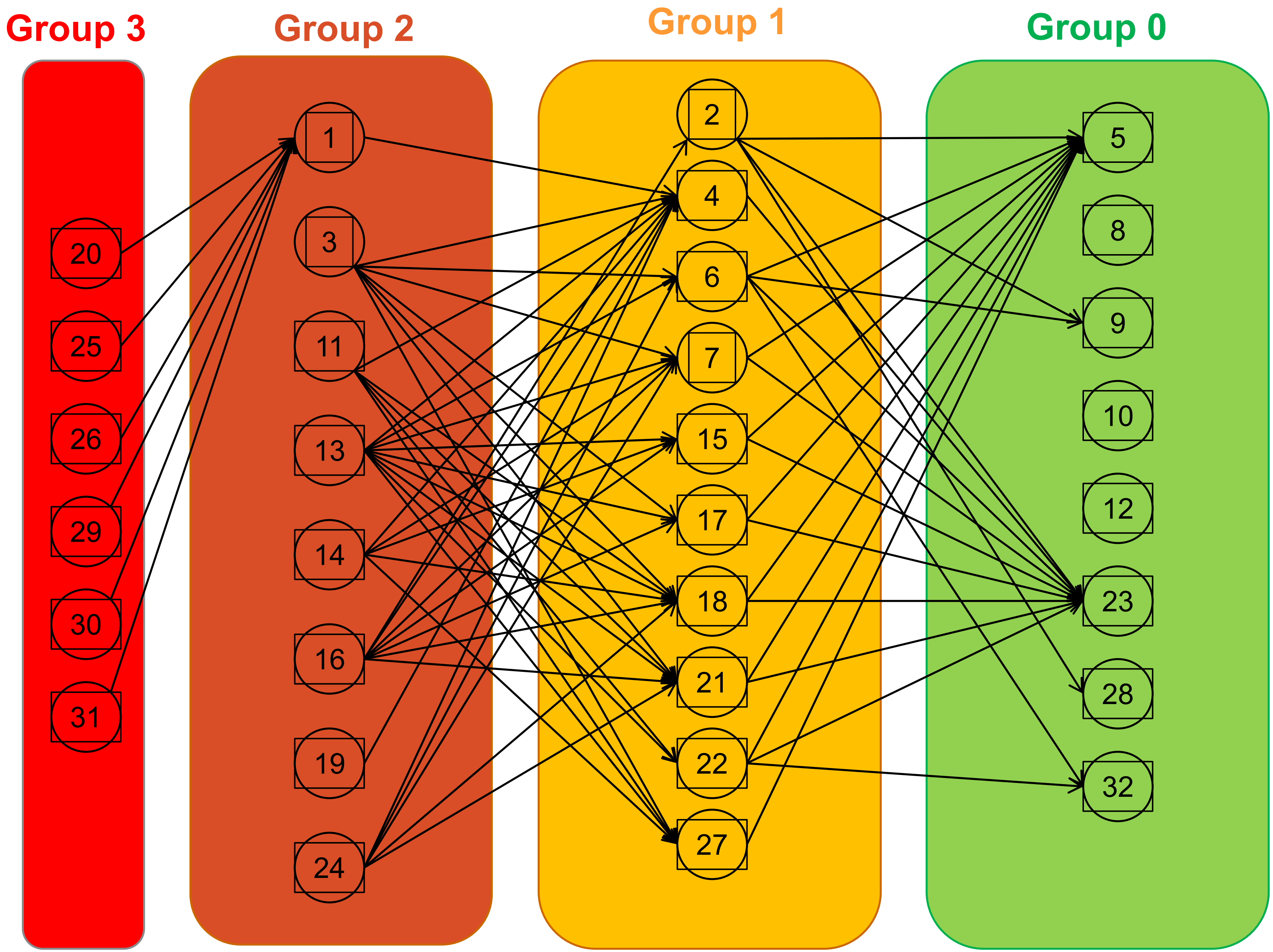
The dependency of the settlement results on the value of the available liquidity

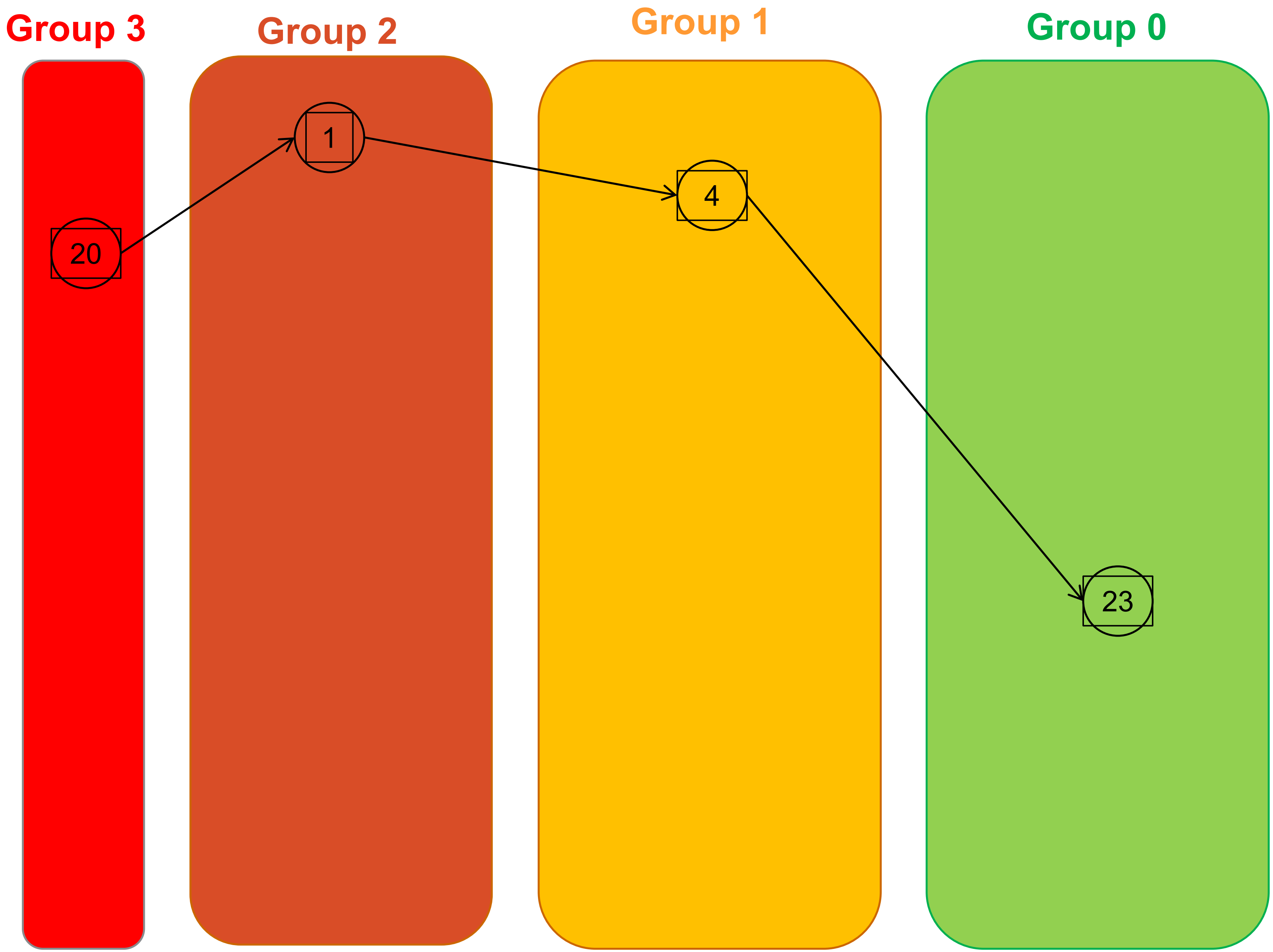




Central Bank liquidity interventions
And
The consequences of unwinding

Liquidity intervention (or unwinding) trigger a well predicted chain of cascading settlement (or rejection).


Group 3
Group 2
Group 1
Group 0
20
25
26
29
30
31
1
3
11
13
14
16
19
24
2
4
6
7
15
17
18
21
22
27
5
8
9
10
12
23
28
32


Group 3
Group 2
Group 1
Group 0
20
1
4
23

Fairness concept suggested by Bech & Soramaki

No fair solution to BCP exists, unless everything is settled.

Maintaining the collateral at minimum

Some 30 bln EUR (as a minimum estimate) can be released from the collateral holdings in Eurosystem, producing no risk.

Bank of Russia
The Central Bank of the Russian Federation

The boundaries of the optimal solution

The boundaries for the optimal solution

$$\begin{cases} 0 \le x_{ijk} \\ 0 \le \xi_{ijk} \\ 0 \le \zeta_i \\ x_{ijk} + \xi_{ijk} = 1 \\ \sum_{jk} a_{ijk} * x_{ijk} - \sum_{pq} a_{piq} * x_{piq} + \zeta_i = B_i \end{cases}$$

$$x_{ijk} - integer$$

$$F \to max$$

$$F = \sum_{ijk} a_{ijk} * x_{ijk}$$

The boundaries for the optimal solution

$$\begin{cases} 0 \le x_{ijk} \\ 0 \le \xi_{ijk} \\ 0 \le \zeta_i \\ x_{ijk} + \xi_{ijk} = 1 \\ \sum_{jk} a_{ijk} * x_{ijk} - \sum_{pq} a_{piq} * x_{piq} + \zeta_i = B_i \end{cases}$$

$$x_{ijk} - integer$$

$$F \to max$$

$$F(x^*)$$

The boundaries for the optimal solution

$$
\begin{cases}
0 \le x_{ijk} \\
0 \le \xi_{ijk} \\
0 \le \zeta_i \\
x_{ijk} + \xi_{ijk} = 1 \\
\sum_{jk} a_{ijk} * x_{ijk} - \sum_{pq} a_{piq} * x_{piq} + \zeta_i = B_i
\end{cases}
$$

$$x_{ijk} - integer$$

$$F \to max$$

$$F(x^*)$$

x^*- optimal solution to BCP, which we don't know

The boundaries for the optimal solution

$$\begin{cases} 0 \le x_{ijk} \\ 0 \le \xi_{ijk} \\ 0 \le \zeta_i \\ x_{ijk} + \xi_{ijk} = 1 \\ \sum_{jk} a_{ijk} * x_{ijk} - \sum_{pq} a_{piq} * x_{piq} + \zeta_i = B_i \end{cases}$$

~~x_{ijk} – integer~~

$$F \rightarrow max$$

$F(x_0)$

x_0- optimal solution to Linear Problem, which is easy to find

$F(x^*)$

x^*- optimal solution to BCP, which we don't know

The boundaries for the optimal solution

$F(x_0)$

x_0- optimal solution to Linear Problem, which is easy to find

$F(x^*)$

x^*- optimal solution to BCP, which we don't know

$F(x_1)$

x_1- Heuristic (feasible to BCP restrictions) solution in the neighborhood of x_0

The boundaries for the optimal solution

$$F(x_0) \geq F(x^*) \geq F(x_1)$$

x_0- optimal solution to Linear Problem, which is easy to find

x^*- optimal solution to BCP, which we don't know

x_1- Heuristic (feasible to BCP restrictions) solution in the neighborhood of x_0

The boundaries for the optimal solution

100%

$$F(x_0) \geq F(x^*) \geq F(x_1)$$

x_0- optimal solution to Linear Problem, which is easy to find

x^*- optimal solution to BCP, which we don't know

x_1- Heuristic (feasible to BCP restrictions) solution in the neighborhood of x_0

The boundaries for the optimal solution

100%

$F(x_0) \geq F(x^*) \geq F(x_1)$

x_0- optimal solution to Linear Problem, which is easy to find

x^*- optimal solution to BCP, which we don't know

x_1- Heuristic (feasible to BCP restrictions) solution in the neighborhood of x_0

The boundaries for the optimal solution

100%

97%

$F(x_0) \geq F(x^*) \geq F(x_1)$

x_0- optimal solution to Linear Problem, which is easy to find

x^*- optimal solution to BCP, which we don't know

x_1- Heuristic (feasible to BCP restrictions) solution in the neighborhood of x_0

The boundaries for the optimal solution

$$100\% \geq F(x^*) \geq 97\%$$

$$F(x_0) \geq F(x^*) \geq F(x_1)$$

x_0- optimal solution to Linear Problem, which is easy to find

x^*- optimal solution to BCP, which we don’t know

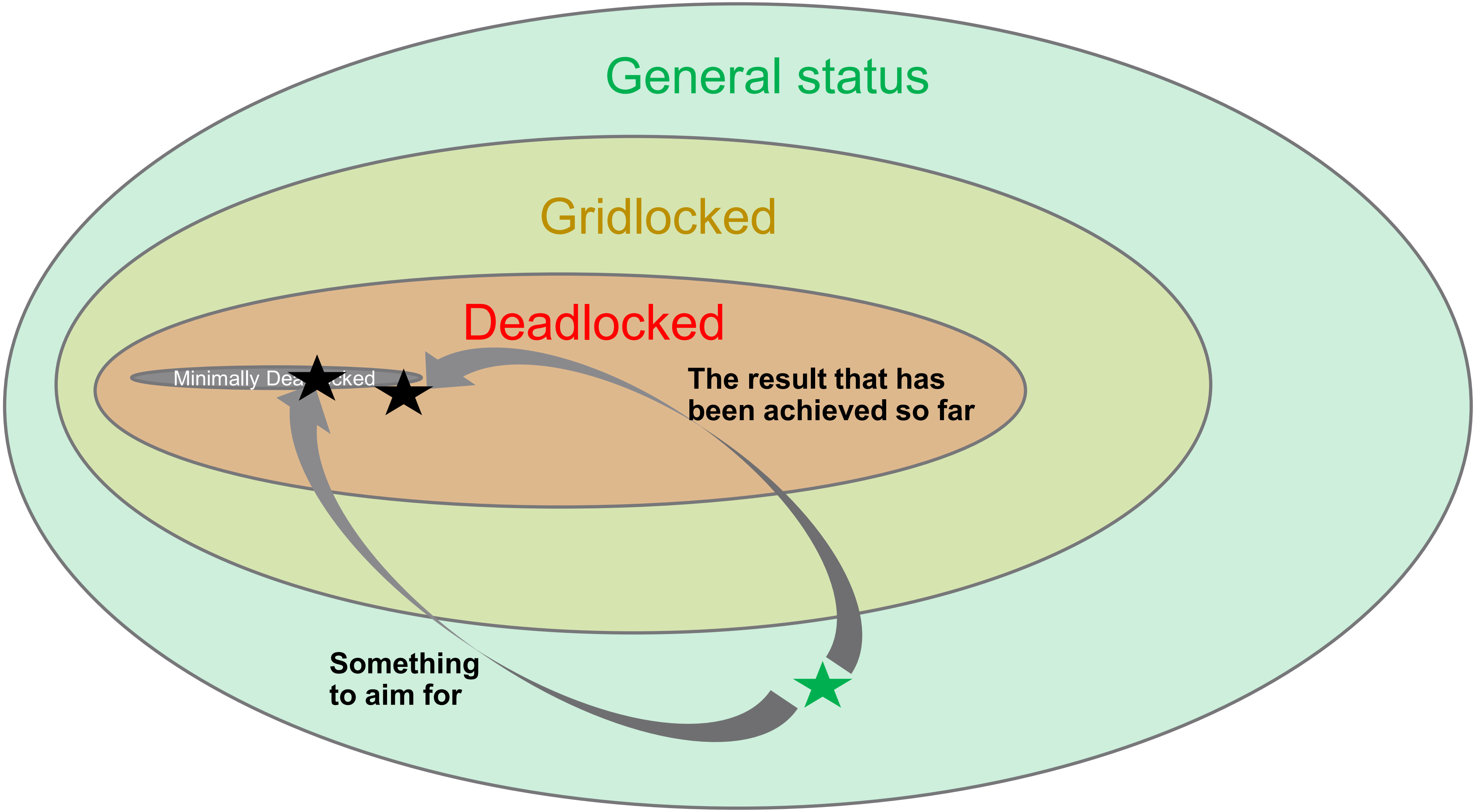
x_1- Heuristic (feasible to BCP restrictions) solution in the neighborhood of x_0

The boundaries for the optimal solution

$$100\% \geq F(x^*) \geq 97\%$$

$F(x_1)$

The boundaries for the optimal solution



Bank of Russia

The Central Bank of the Russian Federation

Thank you for your kind attention