A problem for the OOPSLA'2001 DesignFest

Securities Trade Matching

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Introduction

The system that you are asked to conceive aims to automate a clearing bank's part of the government securities trading business, which involves processing clearing instructions from dealers (sending settlement instructions to the Fed for *deliver* and matching instructions with incoming securities for *receive*) as well as associated bookkeeping and transaction management.

Securities (U.S. Government bonds) are entrusted to "clearing banks", which store them at a few selected "depositories"; bond are traded by professional "dealers" on behalf of actual bond owners. When bond owners want to exchange or buy/sell bonds, they ask their respective dealers to perform the transaction, and dealers ask their respective clearing banks to issue "instructions" to the depositories to perform account movements to "settle" the transaction; see detailed scenario below. The trade is "settled" only once these instructions are executed and duly acknowledged.

Besides stringent integrity, reliability and performance requirements, the solution must satisfy the hard technical problem of "matching" in hard real time the two sides of a bond trade, namely the receive and deliver instructions from both sides.

Problem Domain

The aim of this description is to provide information that is sufficient for analysts and/or designers to describe, in some detail, a computational solution, including hardware and software.

The Business Problem

Relevant players:

- **Securities repositories:** institutions that hold government securities; the main depository is the Fed.

- **Fed:** the U.S. Federal Reserve Bank. The Fed holds money and bonds for each member bank, keeping track via accounts.

- **Clearing banks:** banks that (among other things) handle securities settlements with the Fed on behalf of dealers.

- **Dealers:** financial institutions that perform securities trading (and possible other operations) on behalf of bond owners (and possibly other customers).

- **Bond owners:** persons or institutions who own securities.

Securities settlement

Bonds are financial instruments issued by the U.S. Government, which can be bought and sold in the open market. In earlier times, bond holders actually held a piece of paper, and bond trading involved swapping such documents.

Like any valuable item, bonds could be kept in custody by banks. The ever wider use of computer technologies has meant that nowadays bonds are mere accounting entries stored (actually, recorded) at a few selected "depositories", chiefly the U.S. Federal Reserve Bank ("the Fed"). Furthermore, since the Fed is a closed-membership institution (only national banks hold accounts in it)[1], other bond owners must ask a "clearing bank" to hold and handle bonds on their behalf. To complicate things a bit more, in practice bond owners do not handle their own securities, but ask professional "dealers" to do it for them.

Thus, a many-layered system of trust exists: customers entrust their bonds to dealers, who entrust them to clearing banks, who entrust them to the Fed.[2]

A customer who want to sell its bonds must ask its respective dealer to issue "instructions" to a clearing bank to perform the corresponding transactions; see detailed scenario below. Once these instructions are executed and acknowledged, the trade has been "settled".

An Example Scenario

Let's assume two bond owners, C1 and C2, who retain traders T1 and T2 respectively; T1's clearing bank is BNY, and T2's is Chase.[3] C1 agrees to buy bonds from C2 for some amount of money, and they instruct their traders accordingly. T1 sends a *receive* instruction to BNY (his bank), and T2 sends a *deliver* instruction to Chase (her bank), both of them indicating the money values and the bonds' amount and kind.

Upon receiving the *deliver* instruction from T2, Chase sends a message (called a securities transfer instruction) to the Fed, indicating the bond and money details. The Fed will "settle the trade": that is, it will take the money out of BNY's account and put it into Chase's account, and **at the same time** will move the bonds from Chase's account into BNY's account. Note that as far as the Fed is concerned, this is a transaction between the banks. Once the movements are done, the Fed will send a *notification* to Chase confirming the operation, and will send a securities transfer *advise* to BNY, telling it about the money transfer and the new bonds it holds.

Meanwhile, upon getting the *receive* instruction from T1, BNY will attempt to match it with some *advise* from the Fed. If it succeeds[4], the deal is completed. However, if T1 has moved fast enough (or T2 or the network was slow or whatever), the *receive* may actually arrive before the NY Fed *advise*, and there would be no match at the time; if the matching attempt fails, the

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[1] In reality, there are several Federal Reserve Banks (FRB's), and each chartered bank has an account in exactly one of them, the one corresponding to its geographical region.

[2] The reliability requirements that arise from accounting for these multiple collaborating partners is not a matter of this problem, but just for the curious, let it be said that it's mind-boggling and fascinating.

[3] BNY and Chase together cover 80% of the transaction volume.

[4] Success means finding an advise that matches the bank and amounts involved (money and bonds). There is no notion of "transaction id" at the level of dealers trading.

receive instructions remains "pending" at BNY. If and when a suitable matching *advise* arrives at BNY from the Fed, acknowledgement sent back to the Fed and the deal will have been "settled".

Of course, if the reverse situation happens, namely T1 sells bonds to T2, the dual of the above will occur (BNY will instruct the Fed to perform the actions, the Fed will notify Chase, and Chase will perform the matching).

The settling of a trade involves matching *receives* against incoming *advises* from the Fed, and outgoing *delivers* to the Fed against *notifications* that the transfers have taken place. This matching is the only place where transactions are actually checked, since the Fed merely executes instructions and leaves to the clearing banks to verify validity and correctness of the financial operations. Additionally, some calculations are required right after a matching is done to keep track of some *positions*; the "position of A with B" is the balance currently held in an account that B maintains for A, whether for money or bonds; for example, your checking account balance is your position with your bank. Of interest to a clearing bank are its position with the Fed and the dealer's position with the bank; the customer's position with the dealer is immaterial to the bank.

Anomalous cases

If a *receive* instruction does not match an *advise* within a reasonable time frame (either by timeout or end-of-day), then the trade is reported to the Fed as invalid; the Fed reverses the original account movements, and notifies the other involved bank of this situation.

If an *advise* is received from the Fed, but a *receive* instruction is never received from a dealer, the trade is reported to the Fed as invalid, and the Fed reverses any related account movements.

If a *deliver* instruction is performed, but a *notification* is received from the Fed indicating that this trade has been considered invalid and reversed, then the account movements affecting the dealer issuing the original instructions must be reversed, and the originating dealer must be notified.

If a *notification* is received from the Fed, indicating that a *deliver* has been performed, yet there is no *deliver* that matches such *notification*, then the operation must be reported to the Fed as invalid, and all relevant data must be sent to a separate auditing system.

If the trade is between two bond owners whose dealers trade through the same clearing bank, the process is the same regarding instructions and matching, except that the FRB need not be involved: the bonds and money move only between the internal accounts that the bank itself has for the dealers.

If the trade is between two customers with the same dealer, the trade should not be even known to the clearing bank: the bonds and money move only between the internal accounts that the dealer itself has for those customers.

The Construction Problem

The system that you are asked to conceive aims to automate a clearing bank's side of the government securities trading, which involves processing instructions (accepting dealers instructions and accordingly sending *delivers* to the Fed and accepting *receives* for matching) as

well as associated position tracking and transaction management. The solution you propose must satisfy some additional requirements:

- ❑ **Reliability:** 24x7, non-repudiation, plus the usual ACID properties (vis-a-vis dealers and the Fed).

- ❑ **Performance:** mismatched trades must be reported to the Fed within two hours, and mismatched "notifications" confirming non-requested trades must be spotted and reported back within 2 seconds.

- ❑ **Integrity:** dealers must not be able to draw funds or bonds beyond their position with the bank, and the bank itself must not draw funds or bonds from the Fed beyond its own position.

Any solution that you propose must tackle the non-trivial technical problem of real time matching of *instructions* and Fed *advises*. It is known that a previously built solution required dedicated hardware and a reliable, recoverable in-memory database, in order to meet performance and reliability constraints. Size and frequency data can be given live by the domain expert if requested by the problem solvers.