

Consolidation of Cash and Derivative Markets Technology



臺灣證券交易所

Study completed with the Taiwan Stock
Exchange Corporation for WFE by

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TRADING TECHNOLOGY

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1. Executive summary

The driver for consolidation of markets is to increase efficiencies with an amalgamation of services and expertise, providing members of the Exchange with fewer entities to deal with. A large part of the costs in running Stock Exchanges, and therefore the charges to their members, lies in Technology.

This study examines best practises in respect of the merging of cash and derivatives market technology within a national jurisdiction.

Several Exchanges were targeted who have either merged cash and derivative markets, or who have created a derivative market having established a cash one.

The study showed that there is no clear best practise as such, that each case needs to be examined on its own merits. The study does show that there are surprisingly more reasons not to consolidate technology than to do so.

1.1. *The arguments in favour of consolidation*

Cost savings and rationalisation

Significant savings of up to 30 % can be realised in the reduction of trading systems from two to one. Each trading system needs several environments to be supported for testing, training, member testing, performance and development. All of these require hardware and staff to support them.

Members cost savings

Members experience significant savings through not having to pay for two sets of distinct network connections (not including all of the resiliency connections), systems for receiving market data and for trading in general.

Flexibility of market models, cross asset margining

A single system allows many different products to be traded alongside each other, whether derivatives, fixed income or equities. Cross asset margining can be achieved without integration ; however an integrated system will allow real-time risk management. It should be noted that all the Exchanges studied do not do real-time cross asset margining as its benefits are considered marginal.

Contingent order functionality

The ability to trade derivatives whilst also trading their underlying stocks reduces risk in hedging situations. This is only truly possible at the Stock Exchange on a consolidated system.

1.2. *The reasons that Exchanges have given for not consolidating*

Operational risk

Increasing complexity brings a higher risk of failure or of poor performance. Derivative systems need market configuration on a much greater basis than cash markets.

Lack of congruence between market participants

Some Exchanges have a completely different set of organisations trading cash verses derivatives, thus there are insufficient benefits to members in consolidating platforms.

Members have different systems for trading cash and derivatives

Many members in the established markets have completely different systems for internal trading of cash and derivatives, and thus do not benefit from a consolidated platform.

Ability to manage change on different markets

With different systems, changes can be made to one market without requiring all members to test and redevelop their systems. Derivative markets tend to change more, however only 25 % (on average) of the equities markets participants trade derivatives too, thus the cash market participants are inconvenienced by redevelopment and testing which they do not benefit from.

Performance issues

Keeping the systems separate ensures that problems in one do not affect the other and that in high-volume markets the processing in the central order book is kept to a minimum.

Migration projects are too traumatic, time consuming and expensive

The migration of members from one trading system to another is a highly traumatic project, with many more knock-on projects being spawned internally within members' firms. Members are not very enthusiastic when the consolidated entities do not offer any new business functionality.

A migration project typically takes 2 years.

1.3. Optimal model

The optimal model is one where both the cash and the derivatives systems are based on the same technology, but different servers performing trading, with different versions of software. Members should be able to communicate with the central markets through the same messaging middleware, so that they only have one connection to the Exchange, minimising communication costs. The Exchange also benefits through only needing one set of development, support, maintenance, running fewer testing environments; meanwhile avoids problems with operational risk and performance.

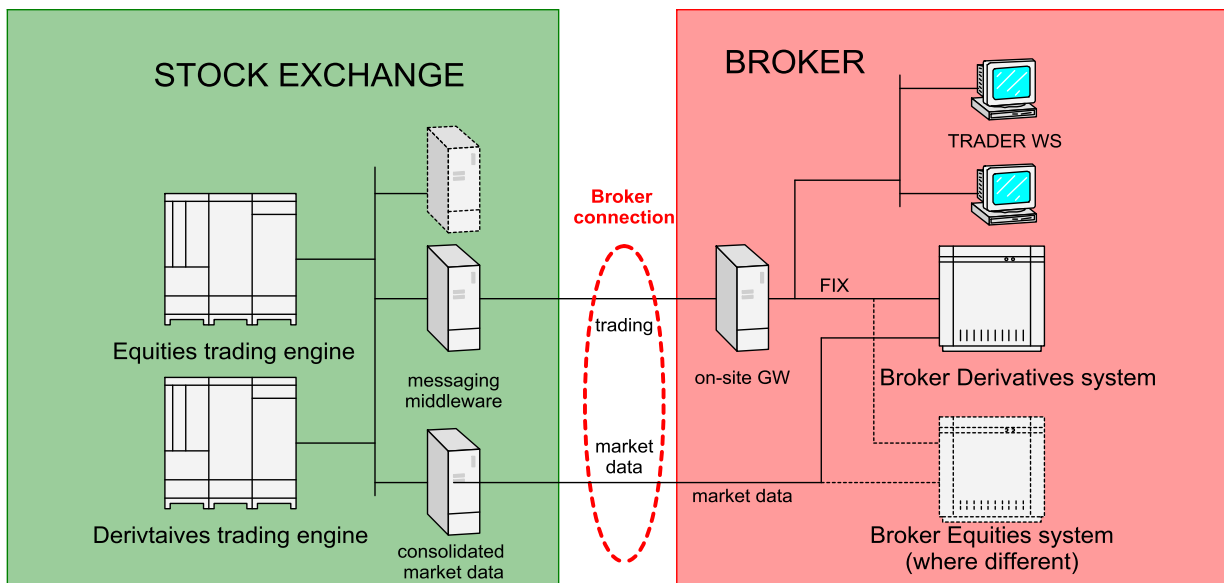


Figure 1 : Optimal model for Cash and Derivatives consolidated systems

Market Data should also be consolidated too, minimising the connections and systems required for members and data vendors. This may be implemented separately from the trading systems themselves.



2. Background to study

The Taiwan Stock Exchange is in the process of merging its market entities together with clearing and settlement into a single organisation. This national consolidation is a business trend, particularly in the Far East where the Hong Kong, Singapore and Korean markets have all consolidated under a single entity within the last seven years.

One of the benefits of consolidating market entities is to bring economies of scale. With the merging of the technology departments, the combined entity needs to take stock of its often divergent applications and rationalise redundant systems and functionality.

However there are no clear examples from other Exchanges as to the benefits in merging the trading systems which support cash and derivatives markets. Some have kept the platforms separate; some have consolidated them onto a single platform. Migrations of members from one system to another attract substantial budgets, but promise substantial savings.

The Taiwan Stock Exchange proposed to the World Federation of Exchanges to conduct a study of consolidation issues with the aim of providing its members with shared knowledge of best practise in this respect.

This report is the conclusion of that study. We have targeted Stock Exchanges with a broad range of experiences in this issue, with a balance of ones who have consolidated and those who have not. We have also tried to include a study from an emerging market, for those many members who have an established cash market and who want to create a derivatives one.

The first part of the report contains the main conclusions of the study, the second part details the individual case studies, listing the reasons for consolidation or non-consolidation, and a description of the systems involved.

2.1. Participating Exchanges

The following Exchanges have been investigated as part of this study :

1. Australian Stock Exchange (ASX), Australia.
2. Budapest Stock Exchange, Hungary.
3. Deutsche Borse Group (DBG), Germany.
4. Hong Kong Exchanges (HKEx), Hong Kong, China.
5. Korean Stock Exchange (KRX), Korea.
6. NYSE-Euronext, Europe.
7. OMX, Sweden and the Nordic countries.
8. Singapore Exchange (SGX), Singapore.

We are extremely grateful to the Stock Exchanges who have agreed to participate in this study and thank them for the time they have spent in gathering this information.



3. Business issues

When faced with the decisions about whether to merge technologies, there are business-related issues and technical ones. The results of the study show that the decision as to whether to consolidate markets onto a single platform has many attributes to consider. As most Exchanges are either for-profit organisations or are intending to become one, the entire issue needs to be resolved down to an investment decision, with a cost-benefit analysis. The business decisions are listed in the following sections :

3.1. Member's perspective

All of the Exchanges interviewed had conducted surveys amongst their members to establish their views on consolidation of technology platforms. Obviously membership buy in to a merger program is vital to carry out a lengthy and expensive project. Topics to investigate with the members are elaborated on in the following sections.

As a general rule, Equities markets are higher volume and have more members. Thus forcing members to migrate from one system is generally easier if it is from the derivatives to cash trading platform. Even then, just the market readiness project to migrate users from one system to another can last up to two years, and is best accomplished after the system has been tested and accepted by the Exchange.

3.2. Budgets required for member spend on connecting to new system

As with any technical change to a Stock Exchange interface, the knock-on projects that it spawns in the membership community can be considerable. In the migration of the ASX's equities markets from its SEATS system to CLICK-XT, one of its largest members reported 50 sub-projects created as a result of the change.

The Exchange needs to understand the impact that a system migration will bring and subsequent financial impact on the member firms. The combined budget for a system migration is roughly ten times the cost of the project to the Stock Exchange. Thus the Exchange needs to be clear about the enhanced business benefits the new environment will bring.

3.3. Congruence of members' activity

From a business perspective, aside from any cost savings from technology rationalisation, the only extra functionality which can be offered on a combined platform is the possibility of contingent orders across derivative markets and their underlying products.

Contingent orders are where multiple orders can be entered into a market with the condition that all orders can only execute if all conditions are met, for example a limit order in an interest rate derivative vs. an underlying fixed income stock. This is useful for brokers in arbitraging across markets and prevents risk from market prices moving in the split second between the order leaving their systems and arriving at the order book(s) on the Exchanges.



Contingent Criteria
This order will be placed upon meeting the following criteria:

Symbol	<input type="text" value="QQQQ"/>	<input type="text" value="greater"/>	Price	<input type="text" value="\$40"/>	Trigger*	<input type="text" value="last"/>
Duration	<input type="text" value="Good Until Cancelled"/>		Time (ET)	<input type="checkbox"/> <input type="text" value="9:30 AM"/> to <input type="text" value="4:00 PM"/>		

Option Symbol [Find Chain](#) **QQQQ MAR 34 C**

Action

Quantity [All or None](#)

Price

Market

Limit \$

Stop \$

Stop Limit

Market On Close

Buffered Limit

Duration

Advanced Orders

Figure 2 : Contingent order entry screen¹

One can have many “legs” to the contingent order forming “strategies”. CLICK-XT has the ability to pre-configure different types of strategies, LIFFE.Connect has the ability for a trader to define one as and when they enter an order.

These contingent orders are required in the case of arbitrage or straddling, which is not practised in all markets. Hence the Exchange needs to establish how much of their members’ business requires trading simultaneously in both markets. A simple assessment of the membership congruence of the markets is a good starting place. In the case of the Hong Kong Exchanges, there are 427 members of the Equities markets with nearly all of the 125 derivative members also being equity members. Thus 71 % of their membership population would not stand to benefit from a technical consolidation. Singapore is much more even, with only 33 % who would not benefit and 38 % who would.

¹ Options express order entry

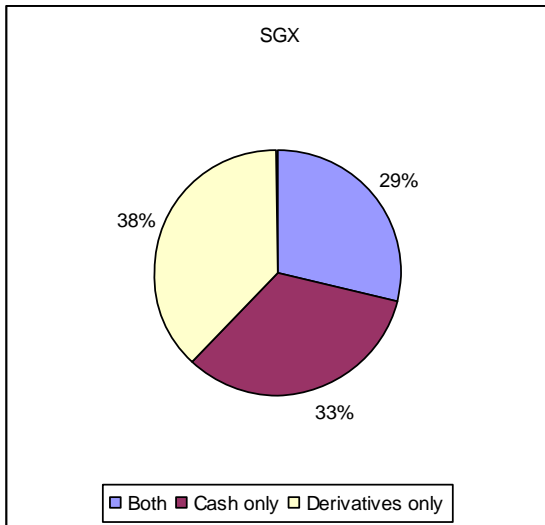


Figure 3 : Congruence of members in SGX

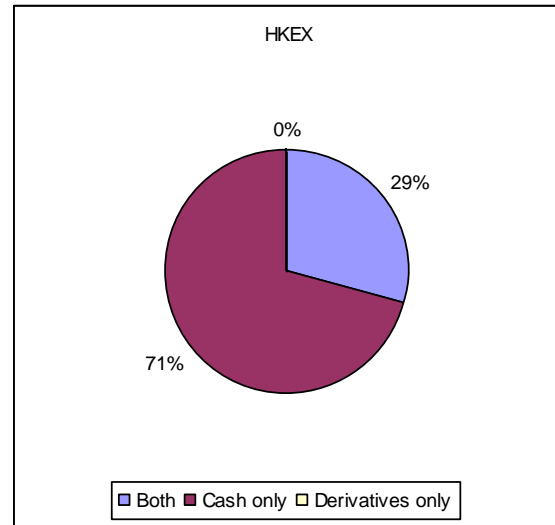


Figure 4 : Congruence of members in HKEx

3.4. Congruence of members technology

In the cases of established derivatives markets, it is generally the case that members have separate systems for trading derivatives and cash. Often the member's derivative system will trade cash as well, and has a separate link into the cash markets, but that member will still have a separate equities trading system. Members in London can have up to four distinct technical connections to the London Stock Exchange, each link interfacing to a different business area's systems.

The Exchange needs to understand exactly how many of its members who trade on both markets, have different systems, and whether they would consolidate their systems, bringing operational benefit and reducing the network costs. If they have distinct systems, there is less likely to be any benefit to consolidation at the Exchange end.

HKEx, OMX and Euronext all cited this as a core reason for not consolidating their systems.

3.5. Differences between markets

Internally, many Exchanges have a separate IT function which is charged back to different markets. Often this IT is outsourced, or the IT function resides in a separate business. Internally also different markets can retain their rules, membership criteria and fees. If these markets are faced with a large consolidation bill for the project to merge the technology onto one platform, they may take a short term view and decided that it is not either affordable or in the members interests.

Functionally, derivatives and cash markets tend to have major differences. Equity markets tend to have more stable, vanilla stocks trading for long periods of time with straightforward order books. Bond markets have a greater emphasis on the primary market; derivatives have varying market mechanisms with series of tradable entities with a short lifespan. Options have series of expiries at differing prices with new series opening and closing according to the movement of their underlying stocks. The derivative markets tend to need configuration changes more often than the cash markets.

Generally, the examples studied show that where consolidation occurs, it tends to be cash markets systems which are developed from a system which trades derivatives. This is because the cash markets are simpler and have a subset of functionality compared to the derivative markets. Examples are CLICK-XT from OMX in ASX and SGX, Xetra which was developed from Eurex, and to a lesser extent the NSC system from AEMS.



3.6. Potential Exchange savings

While technical purists may be keen to have a minimal system environment, a cost benefit analysis needs to be done at the business level. There are significant savings to be made in the rationalisation of systems, especially if there is little in common between them.

Apart from running the core trading systems, there are usually many other system environments that an Exchange needs to operate. These include :

- 1) Disaster Recovery/Hot standby.
- 2) Customer test environments.
- 3) Performance test environments.
- 4) Training environments.
- 5) Internal test environments.
- 6) Development environments.

There are also gateways, support groups, maintenance contracts, helpdesk and application support departments which need to be staffed for each environment. Obviously, there are significant savings which can be realised by eradicating multiple systems within an Exchange.

The ASX decommissioned 17 HP-OpenVMS servers and over 250 gateways when the SEATS system was retired and realised cost savings of 30 %.

3.7. High volume markets

The greatest technical challenge facing Stock Exchanges at present is that of escalating volumes, latency issues and performance. The preponderance of algorithmic trading has resulted in the rate of orders to trades increasing dramatically, in turn resulting in central trading systems being stressed in fast markets. The latency time (the time taken for an order to be entered to an Exchange and receiving a response) is suddenly under scrutiny with trading being measured in milliseconds rather than seconds.

Nearly all the Exchanges interviewed had had to upgrade or re-architect their systems to be able to cope with higher volumes and faster throughput.

The markets interviewed also cited this as a reason not to consolidate technology. High performance systems have to be very stable, so the less functionality there is in a system the better.

When DBG redeveloped Xetra from the Eurex system, they removed the clearing and other derivative-related functionality, making a cleaner more efficient cash trading system.

3.8. Clearing and settlement issues

The other main benefit of merged markets is the ability of members to perform cross-asset margining.

In the derivatives markets, the underlying risk that members expose themselves to by holding derivative positions is calculated on an ongoing basis. There is a possibility that this risk is not evident until the derivatives expire, hence margin calls are made on a daily basis to ensure that sufficient funds are available to meet settlement obligations. In the cash markets where a central counterparty exists, there is also a risk that a member defaulting will cause the entire settlement process to fail. To



avoid this, a guarantee fund is used to ensure all parties can settle. To avoid members needing to tie up large amounts of money, clearing houses allow stock (equities and fixed income stocks) to be used instead of cash, allowing for price volatility.

One of the biggest benefits to merged markets is the ability for stock on the cash markets to be netted off against obligations in the derivative ones, giving significant savings in money held on account. This is only accomplished where there is a single clearing entity across all the markets.

This, of course, can be accomplished without the need to merge the trading systems if margin calls are only made at the end of day. There is still a risk that a member may run a risk intra-day, which clearing houses have been mitigating with intra-day margin calls. In this respect it is useful to have merged trading systems in order to monitor risk positions in real time. Both CLICK and Eurex have (near) real-time clearing modules.



4. Technical challenges

4.1. Project scale

Alongside business issues, there are many technical problems in merging markets. The largest is the complexity of running a migration project. Many Exchanges have consolidated on the back of a requirement to replace old legacy systems, and have been faced with the need to migrate their members to a new platform anyway, when the argument becomes easier.

The introduction of a new trading system is a two-phase process. The first phase is the procurement, development, testing and acceptance of the new system. The second phase is chaperoning the market participants through their system changes, and then going live. Generally this takes a minimum of two years to accomplish in entirety. It is further frustrated by the dependency between the phases. Members need on average 18 months in order to make changes to their internal systems, from first notification to go-live. Thus there is the eventual overlap between the phases, which carries the risk of members needing to test against a system which itself has not been accepted.

In established markets the challenge becomes greater due to high volumes. Most new systems need to not only work well without fault, but have to be proven even in fast markets. This makes the transition between systems more complex, due to the need to run stress testing weekends with the members to check that the central trading system works and that the members systems can also keep up with the improved throughput.

The further problem with running a project which lasts for two years comes from business change. Ideally all changes should be put on hold during this period, however this is practically impossible and change requests are inevitable, which further aggravate the implementation timescales.

It is this project trauma which has prevented many Exchanges from merging their technology.

4.2. A single market increases risk

The operational risk of a combined market is also one of the reasons why Exchanges do not merge their technology.

Equity systems deal with much higher volumes than derivative Exchanges. Of the combined volumes of trades, 20 % are derivatives on HKEx, 21 % on KRX, 30 % on Eurex and 36 % on Euronext (which includes London's derivatives but not cash). Option markets also attract a much higher proportion of quotes, due to movement in the underlying stock prices and the need to update whole series of puts and calls, which can adversely affect the performance of the overall system.

Thus there is an argument to keep the derivatives functionality separate from that of cash in order to minimise the risk of failure and to streamline the processing in the cash markets to enhance throughput.

HKEx cited this as their primary reason for keeping the markets separate.

4.3. Functional complexity of amalgamated system

Derivative systems are more complex, and with greater complexity comes the higher risk of failure. Derivative systems also require constant configuration, which again can raise the risk of a fault manifesting itself. The processing which needs to happen in an order book with contingent orders is vastly more complex than that which manages cash trading. For technical reasons, the processing of the order books on a trading system needs to be a single-threaded process. This is because of the requirement to handle orders strictly in the order they arrive, to guarantee fairness. With latency becoming a critical issue, trading engines need to operate at maximum efficiency, enhancing the argument to keep the markets separate.



4.4. Change management

Trading systems, like any other, do not remain static. There are constant changes driven by the business. These changes result in software development with the usual suite of documentation updates, testing, market awareness, training and implementation. This process is doubled (either in complexity or frequency) if it takes on the requirements of two markets on a single system. If changes are for one market, they affect the participants of the other. Consequently this is also used as a reason to keep the systems separate.

4.5. Backward compatibility, FIX

Backward compatibility is usually sought after in order to minimise the impact on Exchange members, however no two trading systems are alike, and some work is required by brokers (or their solution providers) to redevelop changes to the new trading system.

FIX is fast becoming a standard for Exchange connectivity. If a trading system uses FIX to communicate with brokers, it has the added benefit of making the central system easier to replace.

The Saudi Arabian Stock Market, Tadawul, (not in this study) implemented the Horizon system in 2001. They used FIX gateways to communicate with their members. The Exchange became a major investment centre far outstripping its estimated volumes, hitting a peak in 2006 of 860,000 trades in one day. They needed to upgrade the Horizon system (a system designed for much smaller emerging markets) and recently implemented the SAXESS system from OMX. The project was made considerably faster by the standardisation of the FIX interface. This meant that their members didn't have to make changes to their trading systems, shortening the entire process. The member readiness program was accomplished in a few months rather than years.

4.6. Market data Issues

Market data subscribers are also technical users of the Stock Exchange, and having a single market data feed covering all markets is highly desirable in reducing complexity and network connections. Upgrading the market data interfaces can sometimes be more demanding than that of the trading interface.

It is, however possible to amalgamate market data from multiple trading systems without merging them. The ASX used a market data dissemination system called SCREENS which broadcast amalgamated data both from their old cash trading and derivatives systems. Upon consolidation, the SCREENS system remained in place providing backward compatibility and reducing the need for market data interfaces to be redeveloped or for data vendors to conduct testing.

DBG also use a market data concentrator for broadcasting data from all of their markets, called CEF. This is based on the Cicada Composer product, which is also used in Hong Kong.

4.7. Network rationalisation

One of the major benefits in merging technology between markets is to reduce the number of connections between members and markets. Legacy systems from entirely different Exchanges brings a confusing array of protocols and connections. Multiply this by the need for failover connections, DR and testing circuits, and communication costs can be prohibitive.

Even those Exchanges who have not merged their technology have sought to rationalise their network connections. HKEx did not merge their trading systems, but they recognised that there were significant cost savings and efficiency to be made in the integration of its network infrastructure. Its members used completely different TelCos. This was completely rationalised using a single TCP-IP connection realising a 30 % saving, some HKD20m per annum which was passed onto members.

The KRX has a variety of connections and network protocols for its newly merged markets. It uses x25 circuits for both its equities markets and two different sets of TCP-IP leased lines for its fixed income

trading and derivatives. Their Next-Gen architecture will unify all of these interfaces under one TCP-IP connection.

5. The optimal model for integration of systems

The architecture that most Exchanges have chosen (or arrived at) is one where there are separate trading engines for the different markets, each of which communicates through the same messaging middleware. This is shown in Figure 5.

This design allows most of the benefits listed in section 3, but manages to avoid many of the risks. Changes can be applied to either market at the trading engine level without the need for changes to the messaging middleware. Processing can be complex on the derivatives market without affecting the cash market's performance. Importantly, there is only one connection and API at the broker end for accessing both markets, realising all the network savings and any broker benefits.

This is the configuration that DBG have with Eurex and Xetra, the SGX will have with two versions of CLICK, and the Budapest Stock Exchange have with two versions of the X-Stream system.

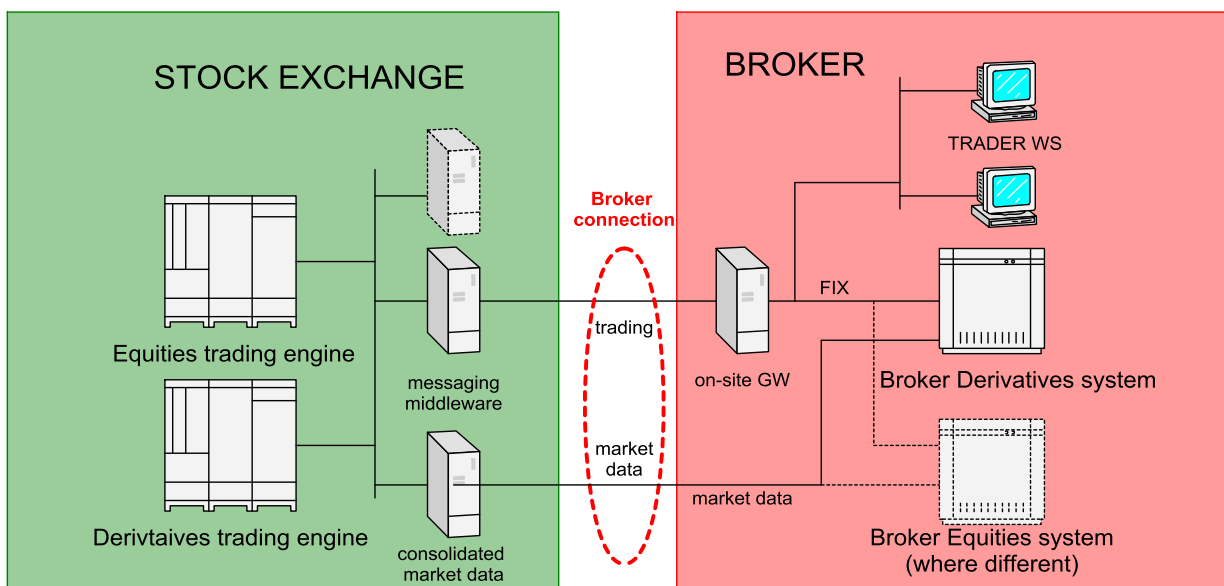


Figure 5 : Optimal consolidated model

The separation of the systems, (which in all cases are running different versions), bring other benefits. There is only one help desk, support and maintenance crew needed for each system. Development staff can work on both systems but at different times, levelling out the resourcing problems which development projects invariably suffer from.



6. Start-up derivative markets

Many WFE members run markets which are at an earlier stage of development than many of the ones studied. They are thus faced with the prospect of developing a derivatives market after establishing a cash one. The issues that these Exchanges face are :

- A start-up derivatives market may have unproven volumes, thus an expensive trading system capable of handling large volumes may not be necessary
- It is critical to make connectivity and cost of entry as low as possible to encourage members to join
- It may take some experimentation with different products before it is apparent which ones will trade well
- The clearing (margining) requirement is likely to be new for the derivatives market, as is the clearing entity.

In terms of a system solution, many equities trading system products can support derivatives as well. Using the “optimal model” the best solution would be to clone the equities trading system and redevelop it into a derivatives system, using the same messaging middleware for connectivity to participants. This then ensures that the brokers can access the markets without having to install new network connections or on-site servers additional to the cash markets. The separate server also minimises the impact on the live markets, although volumes are less likely to be an issue in this case.

The state of the cash trading system needs to be considered, so a study is still required covering the following issues :

- The age and general health of the incumbent system
- Whether there is a development team or software house capable of re-engineering the system (given that modifications may well be needed to the messaging middleware too).
- The architecture of the incumbent system – whether the messaging middleware really allows a multi-market configuration without significant and traumatic re-design.

Exchanges should avoid having to do changes to the existing system, hence a radical re-design of the incumbent system, plus development of new functionality will generally be too complex for any in-house development team. The greatest project risk is usually in the time that such a redevelopment takes.

Experience from other Exchanges who have embarked on a redevelopment of their trading systems is that the project takes four years (as a very approximate rule), whereas the implementation of a product from a vendor takes 18 months to two years.

The fastest way to get any electronic Exchange up and running is to use an ASP offering from another Exchange, which can be completed in as little as 6 months. This may be an advantage if you wish to attract a more international derivatives trading audience who are already connected to a larger market, however it will become difficult for any Exchange to later migrate to their own systems.

In the event that the legacy system is beyond safe re-development, the purchase of a new system is desirable, but one which can also support the cash markets in the future.



7. Conclusions of study

We would like to thank the participating Stock Exchanges in sharing information on their systems and strategies. These real-life examples prove that the decision about whether to integrate cash and derivative systems needs to be examined on a case-by-case basis, considering the incumbent systems, member's set-up and requirements, and congruence of participants.



8. Case Study 1 : Australian Securities Exchange

The Australian Securities Exchange (ASX) is one of the world's top 10 listed Exchange groups, measured by its market capitalisation. ASX group was created through the merger of the Australian Stock Exchange and the Sydney Futures Exchange.

ASX group operates under the brand, Australian Securities Exchange.

The Australian Securities Exchange spans the markets for corporate control, capital formation and price discovery and functions as an operator, supervisor, central counterparty clearer and payments system facilitator.

The diverse domestic and international customer base of the Australian Securities Exchange includes issuers of a variety of listed securities, corporates, investment banks, trading banks, fund managers, hedge funds, CTAs, proprietary and retail traders.

Prior to the merger with the SFE, the ASX was predominantly an Equities Market which also traded derivatives. ASX successfully consolidated their trading systems onto a single platform in 2006. This case study describes the decisions and factors that led ASX to consolidate its markets onto a single system, the benefits they gained from doing so and the process by which they achieved this. At the time of writing, it is one of the largest Stock Exchanges to achieve a consolidation of existing systems.

ASX group has not finalised any decisions about how to whether to merge the SFE component systems with ASX ones. This case study concentrates on the activity within ASX prior to its merger with the SFE.

8.1. Description of the technical environment prior to consolidation

In 1987 the Australian Stock Exchange was formed through the amalgamation of the six state-based Stock Exchanges. Under the state-based Exchange model equities had been trading since 1861.

The ASX originally commenced the implementation of a fully electronic market in 1987 with the introduction of the SEATS trading system. This system was written bespoke for the Australian Market with the assistance of a local software vendor, and subsequently developed, maintained and supported in-house. This system was developed in COBOL and ran on HP Alpha with the OpenVMS operating system. It utilised on-site servers, and thick-client front ends. SEATS was significantly updated in 1997 with the launch of an Open Interface protocol based upon FIX for the electronic submission of equity transactions.

Floor based Derivatives trading in Australia commenced in 1976. In 1997, with the implementation of a fully electronic trading system (CLICK) developed by OMX, floor based trading ceased. CLICK was based on HP-Alpha OpenVMS which was in line with ASX's (then) strategy for preferred platforms, rationalising the support services at the technical end, and also allowing a simplified network for connectivity to brokers.

During the mid to late 1980s ASX also developed a single market data distribution platform called SIGNALS which broadcast both aggregated and disaggregated data from both markets. This was also developed in COBOL and C and ran on HP Alpha VMS.

This is summarised in Figure 6, simplified by not showing resilient connections or recovery channels, or any other ASX systems.

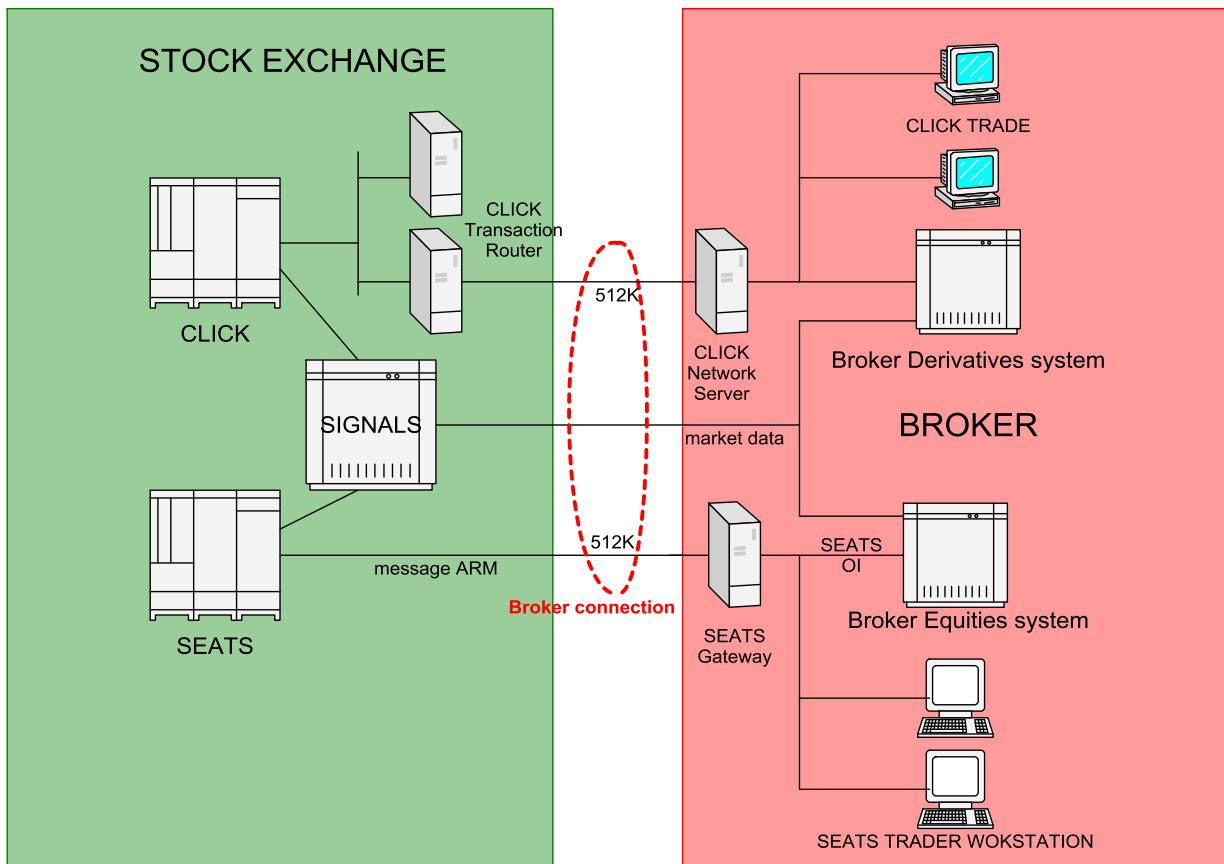


Figure 6 : ASX system interfaces to brokers (simplified)

8.2. Factors which led to the consolidation

There were several factors which led to the consolidation of the systems explained in the following sections :

8.2.1. The need for a SEATS replacement

The SEATS system had undergone a significant update in 1997 and would need to be replaced or require significant re-engineering to last 10 more years. Whilst performance was considered sufficient for the market volumes at the time of the study, predicted growth would outstrip its current capacity in the medium to long term.

A study was undertaken into the different options available to the ASX in 2003-4. At the time ASX realised that needing to revamp one system would give them the opportunity to rationalise their trading systems into one. Coinciding with the study OMX announced that CLICK would be upgraded to include equity trading functionality. The rebranded OMX solution would be known as CLICK XT™

Thus the choices were seen as being :

- 1) Transfer all products onto a redeveloped SEATS platform.
- 2) Transfer all products onto CLICK XT.
- 3) Implement a completely different system for the equities market and/or the derivatives market.



ASX performed a study of other systems available on the market, but concluded that it would be too significant a change for the customer base to move both equities and derivatives onto a brand new platform with a new front end and electronic interface. The option of redeveloping SEATS would also be a higher risk strategy given that trading systems are largely commoditised and would require significant effort and cost to define, build and test. Thus the implementation of the equities market onto CLICK XT seemed a viable option, as 50 % of the equity market participants were also derivatives market participants and thus already had CLICK connections and infrastructure installed.

8.2.2. Rationalisation of systems, resources and related costs

In rationalising the number of core trading systems, the ASX would also rationalise the equivalent development, testing, performance, training and disaster recovery environments, resulting in space being freed up in their data centres. The numbers of support, development and maintenance staff would also be reduced. This all led to significant savings in operational costs and was one of the drivers to consolidate the systems onto a single platform.

8.2.3. Member benefits

The Exchange participants would also benefit from having only a single connection. As mentioned previously, about 50% of members were users of both the SEATS and CLICK systems. This would bring savings in only needing to manage one helpdesk and support services at the Exchange end. Savings by broker varied depending on their internal systems and hardware requirements.

8.2.4. New functionality

With the markets being traded on a single platform, it would be possible to have more advanced strategies for trading which allow contingent orders to be placed on derivatives and their underlying stocks and executed in the same order book at the same time. On other markets, these have to be managed at the broker's end, which often proves to be difficult to execute providing a hedging risk given the latency between brokers systems and the Exchange's. The CLICK XT system is highly configurable and thus it is possible to introduce new products without the need for software changes.

8.3. Approach to migration from SEATS

ASX signed for the delivery of the integrated trading solution on CLICK XT with OMX in June 2004. There followed a development and acceptance phase, after which the market rollout was addressed. The upgrade of the existing version of CLICK to the new CLICK XT for the derivatives market was anticipated to be relatively straightforward, and this became the first phase of the rollout in July 2006.

The migration of the equities markets was a significant project which required a great deal of membership communication and co-ordination.

As 95 % of ASX participants and information vendors had direct connections from SEATS into their own internal order management and information systems, the participants were therefore required to undertake significant development projects to ensure they were ready for the launch of the integrated market. ASX took the decision prior to the launch of the project that it would develop its own version of the CLICK XT API documentation specifically for the Australian market, and hosted technical workshops to enable the development groups of participants to understand how to make necessary changes. Both of these actions proved to be very successful with all participants and third party vendors passing ASX certification testing prior to launching the new system.

There were also many users of the SEATS Trader Workstation who had to be trained on the use of CLICK Trade XT, which was less reliant on keyboard and more reliant on the use of a mouse. Examinations were required for all the traders (some 800) in order to be licensed to trade on the new system. 300 Derivatives users were required to attend training only as they were familiar with the CLICK workstation.

The progress towards the transition required market wide conformance testing and numerous rehearsal weekends. The market transition from SEATS to CLICK XT was phased over two implementation weekends. The warrants and fixed income markets were moved in September 2006 and the equity markets in October 2006

8.4. Technical environment post trading platform merger

The environments are thus simplified onto a single system as shown in Figure 7. Very simply, both equities and derivatives systems now connect to CLICK XT via the OMX API, requiring a single transactional connection. The savings in system environments is significant, requiring half the server space occupied by running two types of trading system.

The market data system SIGNALS was not removed or changed, providing backward compatibility for data vendors, also minimising the amount of change experienced by brokers. SIGNALS has been updated and rebranded as ReferencePoint since the implementation of CLICK XT.

For the purposes of clarity, resilient configurations, recovery channels or DR connections are not shown in Figure 7.

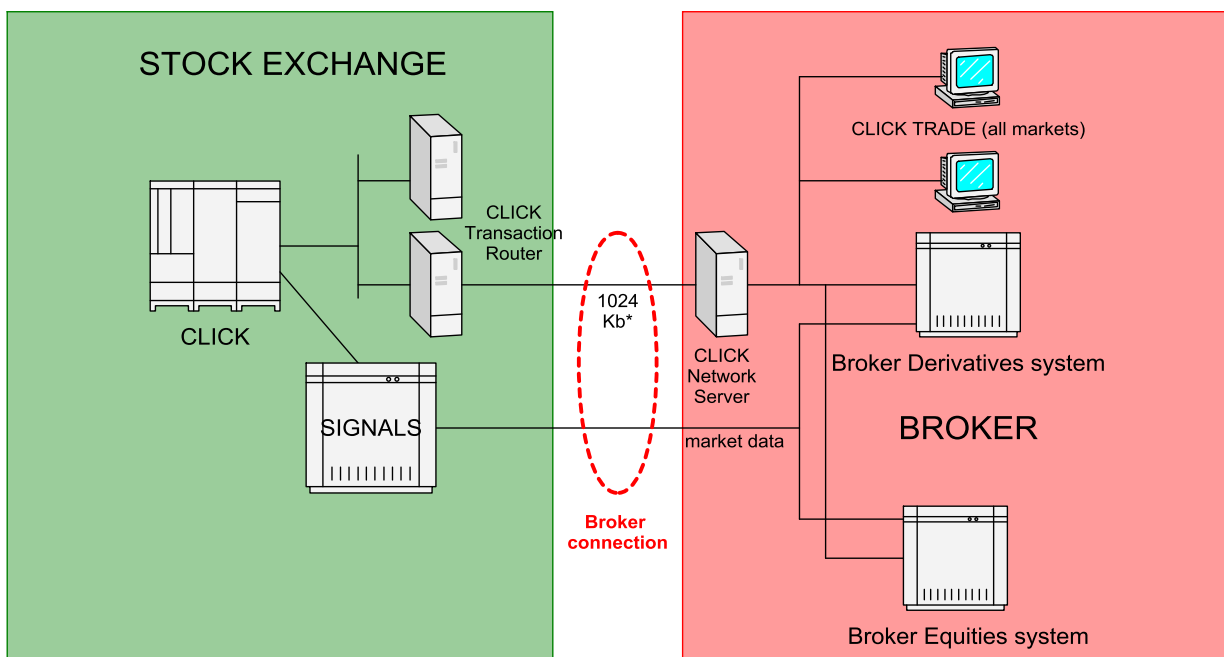


Figure 7 : ASX's systems post consolidation (simplified)

Bandwidth

The growth in trading volumes required the existing systems' bandwidth connections to be expanded prior to the new system. ASX took the opportunity to upgrade the new requirements (which were approximately 192kb higher than the combined systems) and offer 3 levels of market access as part of the major network upgrade.

These were :

- 1) 512KB for a single market access (i.e. replicate the old SEATS or CLICK market access).
- 2) 1024KB for access to all markets (both SEATS and CLICK from the same site).



- 3) *2048KB was offered to larger participants and market makers to satisfy their demands for reduced latency and faster recovery times.

It should be noted that although the new system required a higher bandwidth it was scaled to cope with higher trading volumes than the trading systems it was replacing.

8.5. Changes to environments :

As mentioned earlier, there were significant savings in the reduction of the number of environments needed by the consolidation of systems. Below is a list of the environments and the re-assignment of hardware (where possible).

Production live

- 1) SEATS Production system with 3 backend servers and ~350 gateways. (Decommissioned)
- 2) CLICK production system with 3 backend server and ~250 gateways. (Redeployed hardware to QA)
- 3) New consolidate system (ITS) 5 backend servers and 420 gateways, (re-used production SEATS GW and existing CLICK gateways) grown to 460 gateways with new participants and additional participant sites.

QA environments

- 3 x SEATS System test environments (5 servers) (decommissioned)
- 2 x CLICK system Test environments (5 servers) – upgraded to new system
- 1 x new performance environment for new system (5 servers – old redeployed CLICK production hardware)

External Test environments (3rd party and brokers)

- 5 x SEATS - Decommissioned
- 2 x CLICK – Upgraded to new systems
- 1 x new performance environment (new system)

Development environments

- 3 x SEATS - Decommissioned

Training

- 1 x SEATS – Decommissioned
- 1 x CLICK converted to new CLICK



9. Case Study 2 : Budapest Stock Exchange

9.1. Background to the Budapest Stock Exchange²

The Budapest Stock Exchange Ltd. is the key Exchange for the Hungarian Stock market, being the official trading platform for publicly listed securities.

The continuously widening range of products available at the Budapest Stock Exchange can be divided into three clearly separable categories. The equities section has been operating since the very beginning of the BSE. Aside from equities, this section also includes the trading of investment fund units and compensation notes. The debt securities section is dominated by government bonds, however mortgage bonds and corporate bonds alike enjoy an increasing popularity. The derivatives section is the youngest and most dynamically developing section of the Exchange. It includes BUX index and equity futures and options, as well as currency and currency and interest rate futures.

9.2. The introduction of the Equities and Derivates markets at the BSE

The Budapest Stock Exchange followed a similar story to many of the Stock Exchanges from countries in the former Soviet Union. The Exchange itself, although first being established in 1864, had a reduced function during the years of communism. With the collapse of communism in the late eighties and early nineties, and the adoption of western-style free markets, the Stock Exchange rose to prominence in the nation's economy.

From 1993 the BSE used a system called CMSS (Central Market Support System) from Transic, a UK-based company. This primarily supported the floor based operations. The Exchange made an investment decision in 1997 to go fully electronic and purchased Computershare's ASTS system (now part of OMX and branded as X-Stream). The ASTS system had already had cash and derivative trading functionality built into it from being installed in the MICEX Exchange in Moscow, plus several other equities and fixed income Exchanges.

The Computershare supply agreement bought them two phases of implementation, the first being the equities market, and the second being a new derivatives market.

The equities market was already established but as a quote-driven model with much trading taking place on the Exchange floor, with prices being displayed externally on a data dissemination system. The installation of the equities market was thus a partial "big bang" and was accomplished successfully in 1998.

9.2.1. Derivatives roll-out

Derivative trading started in 1995 on the floor, some futures trading was migrated to the equities system in 1999, but the fully electronic derivatives system came later in 2000. Additional functionality was needed to the purchased ASTS system specifically for the derivatives market.

² From the BSE website



The ASTS system is a three-tiered system with a messaging middleware called “TSMR”. The flexibility of the system allowed multiple market servers at the Exchange end, whilst brokers could communicate through a single on-site gateway.

Thus for derivative testing prior to go-live, a second server was installed at the Exchange, running the derivative software. This proved to be a successful configuration, and was kept for the go-live, even though the BSE originally intended to run the equities and derivatives trading on a single server.

The BSE keep different versions of software on each server.

The benefits that the BSE has from this configuration are :

- Events on either markets do not upset the performance of others
- Specific functionality for one market is not installed on the other, making the systems operate more efficiently, such as the Bond Market primary auction which is not needed on the derivatives markets.
- Configurations and changes can be applied to the central market transactional server individually without introducing operational risk to the other market.
- Brokers still have a single connection to the Exchange(s)
- Market Data Vendors also have a single connection.
- A single interface to the clearing house allows cross-asset margining.

At the time of writing there are 38 members of the equities market, of who 22 trade derivatives.

9.3. Description of the consolidated technical environment

ASTS is a highly distributed system allowing different servers to communicate on a common messaging bus. The entire system is based on HP-UX (including the gateway servers).

The central transaction servers hold the central market order book while other servers may be added to do peripheral tasks such as interface to the clearing house, market supervision and data dissemination. The same servers act as interfaces to Broker systems via the ASTS API and to Trader Workstations.

A central database server keeps transactional data, market configurations and other persistent data for both markets.

The front end trader workplaces have different applications for the equities and derivatives markets ; however these can run on the same workstation.

The connections are shown in Figure 8. The diagram is simplified and does not show resilient configurations, recovery channels or any disaster recovery connections.

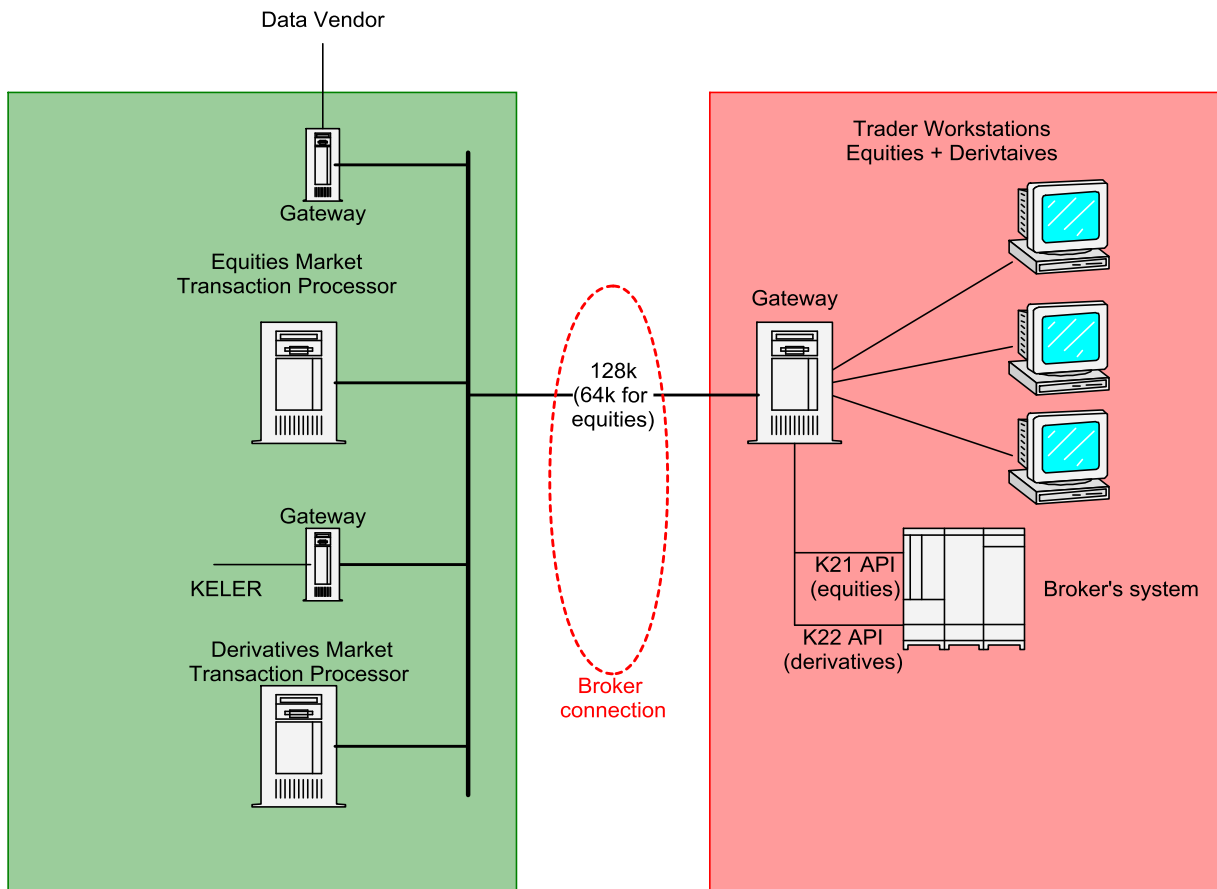


Figure 8 : Central trading systems and broker connections (simplified)



10. Case Study 3 : Deutsche Börse Group

Deutsche Börse Group occupies a leading position in the international Exchange landscape with its broad business portfolio.

The Deutsche Börse Group (DBG) is the world's largest Exchange organization by market capitalisation. Deutsche Börse Systems AG is a full subsidiary of Deutsche Börse AG. It was formed in May 1997 from the IT divisions of Deutsche Wertpapierdaten-Zentrale (DWZ) and Deutsche Terminbörse (DTB). Deutsche Börse Group consists of Equity Trading on the electronic XETRA platform and the floor of the FWB Frankfurt Stock Exchange, Derivatives on the Eurex platform (jointly owned by SWX), clearing through Eurex Clearing AG (ECAG) and Clearstream, settlement through Clearstream and the generation and distribution of trading data through their Information Services division.

Deutsche Börse sees itself as a transaction engine, which builds, loads and operates systems beyond geographical or political borders. The Group has about 3,000 employees at its locations in Germany, Luxembourg, Switzerland, Czech Republic and the USA as well as in representative offices in London, Paris, Chicago, New York, Sao Paulo, Hong Kong and Dubai.

At the heart of Deutsche Borse groups operations are two systems. Xetra, which hosts mainly equity market trading and Eurex, which supports the derivatives business.

This case study looks at the decisions which the organisation made to deploy these systems and the operational benefits that it brings.

10.1. The evolution of the technical architecture at Deutsche Borse Group

The original trading system was developed by SOFFEX, part of the Swiss Stock Exchange (SWX) for the Swiss derivatives market in 1987, running on HP-Alpha VMS using the RTR messaging middleware. This system was then developed further into the Derivatives system at the Deutsche Terminbörse (DTB) in 1988.

In 1997 Deutsche Börse (Frankfurt Wertpapierbörse – FWB) was faced with the need to revamp its equities trading system and decided to redevelop a version of Eurex rather than implement an entirely different system or to merge the derivatives and equities business onto a single platform. They found the configuration desirable for the following reasons :

- Separate market servers at the Exchange minimises the risk in implementing a new market.
- The interfaces to brokers were still uniform, minimising the need for brokers to support multiple connections.
- Much of the functionality in the derivatives system was not needed in the Equities systems, especially the clearing functionality. The removal of this optimised the performance of equities trading on Xetra.
- It is relatively easy for a derivatives system to be made into an equities trading system, as the equities functionality is simpler. It is generally a subset of that required for derivatives.
- Having development and support groups on similar systems mean that they are able to move developers from one system to the other thus smoothing resource allocation for different projects. Deutsche Borse Group has a schedule of releases every six months, one on Xetra and the other on Eurex.
- The same helpdesk and support operations can solve problems on both markets.



The DTB derivatives market was then merged with SOFFEX in 1998 to form Eurex. Eurex Frankfurt AG, owned by Eurex Zürich AG, succeeded DTB GmbH as operator of the German financial derivatives market (Eurex Deutschland). Both DBAG and SWX maintain a 50 % stake in Eurex Zürich AG.

10.2. The technical environment of Deutsche Börse Group

XETRA

The XETRA system is the Deutsche Börse Group's (DBG) flagship system. It is the main electronic trading system for equities in Germany and operates as part of the Frankfurt Stock Exchange (FWB). The same system also supports trading on the Irish Stock Exchange, Austrian Stock Market, European Energy Exchange and Eurex Bonds Exchange.

The system is based on HP Alpha OpenVMS and uses a proprietary messaging middleware to ensure transaction processing and resiliency. The architecture is essentially four-tier with HP Alpha servers for the trading engine and communication servers (so called Access Points) as well as onsite MISS (Member Integration System Servers) and an option of XETRA workstations or a MISS API to connect to a broker's system. There are also a variety of FTP downloads of new stocks, reports and transaction charges that are despatched to the MISS servers on an overnight basis.

XETRA was developed by Deutsche Börse Systems AG together with Accenture (then Andersen Consulting) and went live in November 1997. Today, 261 market participants in 18 countries are connected to the system. At peak times, Xetra processes up to 840,000 trades per day.

A simplified technical diagram is included in Figure 9. It does not show resilient, recovery or DR connections. There are 388 members of Eurex (December 2006³).

³ 2006 Factbook Deutsche Boerse Group

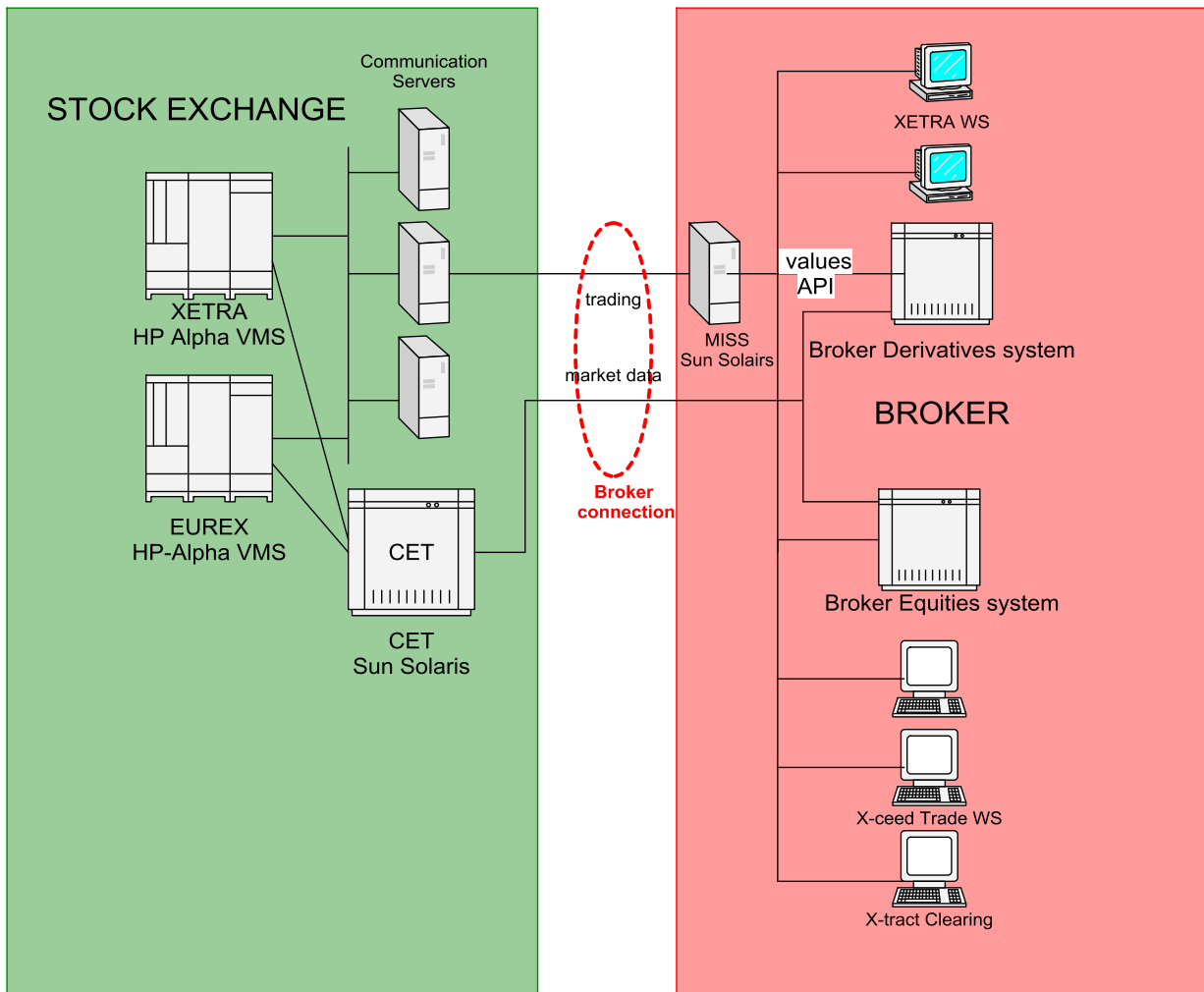


Figure 9 : Xetra members' connection (simplified without resilient connections)

Eurex

Eurex is the brand of both a derivatives Exchange and a system. The architecture of Eurex is similar to the Xetra architecture. Access Points - over and above those in Germany and Switzerland - have been set up in Amsterdam, Chicago, Dubai, Helsinki, London, Madrid, New York, Singapore, and other locations. The MISS servers allow connection to Eurex as well as Xetra, the clearing systems for Eurex and the CCP (central counter-party) clearing system. There are front-end applications that are available for trading on Xetra called @X-ceed and for access to the clearing system @X-tract.

The clearing application is a part of the Eurex system, which monitors in near-real time the risk positions of the Eurex members, allowing for intra-day margin calls or trading limits. This is required in the derivatives markets to manage the exposure of the derivatives positions, but is not needed in the Equities or fixed income markets. Cross-collateralisation is possible between the two markets.

The clearing application access to the clearing system is through the same VALUES API for Eurex and for Xetra.

Bandwidth

For Eurex, a 1Mbs bandwidth connection is required. Standard connection for Xetra is currently 512Kbit/s. 1Mbs and 2Mbs connections can also be ordered. 1Gbs can be achieved for Xetra and Eurex connection by participants in the "Proximity Services" initiative offered by DBG (where market



participants' trading hardware and software can be operated at a site geographically near to Exchange servers with LAN connection).

10.3. Market Data

Some market data can be subscribed to through the MISS servers. Otherwise, Market Data is consolidated through the CEF application, which is an implementation of Cicada's Composer product. This normalises information from different markets and standardises their output. This implementation is on Sun Solaris.

10.4. Deutsche Börse Group IT strategy

Although the systems have been in existence since 1988, both the Xetra and Eurex systems have been considerably redeveloped, and today no code from the original system implementations is left in performance critical parts of Xetra and Eurex.

The service that DBG offer in respect of its technology reflects their investment in a particular policy which they have not wavered from in almost twenty years. They also recognise that redevelopment of existing systems is faster than implementations of new ones, for new business offerings such as the addition to Xetra of the Energy Exchange (EEX) based in Leipzig. This project was completed in only 15 months from the initial approach by EEX towards DBG to readiness for trading. Another example was the addition of the Irish Stock Exchange which was accomplished in six months.

The fact that DBG has not changed its strategy or approach to their core system design is also a reflection of the accuracy of their initial choice of technology, but also is due to their CTO who has remained in the same position, bringing stability to the Technology division. This in turn reflects the DBG's approach to running Exchanges, which treats technology as a core differentiator between them and their competitors and is afforded a high priority in the organisation as a whole.



11. Case Study 4 : Hong Kong Exchanges

Hong Kong Exchanges and Clearing Ltd is the Stock Exchange of Hong Kong. HKEx is the holding company for The Stock Exchange of Hong Kong Limited (SEHK), Hong Kong Futures Exchange Limited (HKFE) and Hong Kong Securities Clearing Company Limited. With a total market capitalisation of over US\$2.124 trillion as of as at July 12 2007, the HKEx ranks fifth in the world by market capitalisation of listed companies.

HKEx was formed in March 2000 to bring trading and settlement on Hong Kong's cash and futures Exchanges together under a single umbrella company, as part of Hong Kong's strategy for enhancing its financial infrastructure. HKEx subsidiary companies include the Stock Exchange of Hong Kong (SEHK), the Hong Kong Futures Exchange (HKFE), and the Hong Kong Securities Clearing Company (HKSCC). HKEx is a limited company who went public in June 2000 and whose own shares are traded on the SEHK. As part of this there is a unified IT division, which is in the process of replacing legacy systems with new technology.

Traded products on the Main Board include equities, warrants, debt securities, unit trusts and mutual funds. There is also a Growth Enterprise Market (GEM) for companies that do not qualify for the Main Board. Traded derivative products include : index futures and options, interest rate futures, currency futures, and local and international stock futures and options.

11.1. Technical overview of the HKEx's trading systems.

11.1.1. Equities and fixed income

HKEx launched its third generation Order Matching and Execution System (AMS/3) in 2000. This is a bespoke application running on HP Himalaya Non-Stop platform implemented as a three-tier architecture with Open Gateways servers running Windows 2003 Server, allowing connectivity to broker's systems, and MWS servers which drive front-end trading terminals.

In February 2001 HKEx introduced its order routing service (ORS) which allows financial service providers with Internet, mobile phones and other electronic order collection channels to forward investor orders to broker systems via their AMS/3 gateways for authorisation by brokers before such orders are directed to the AMS/3 host for execution (see Figure 10). The system shown is much simplified and does not encompass any resiliency or disaster recovery configurations.

All AMS/3 systems are supported and maintained by HKEx Information Technology Division in-house.

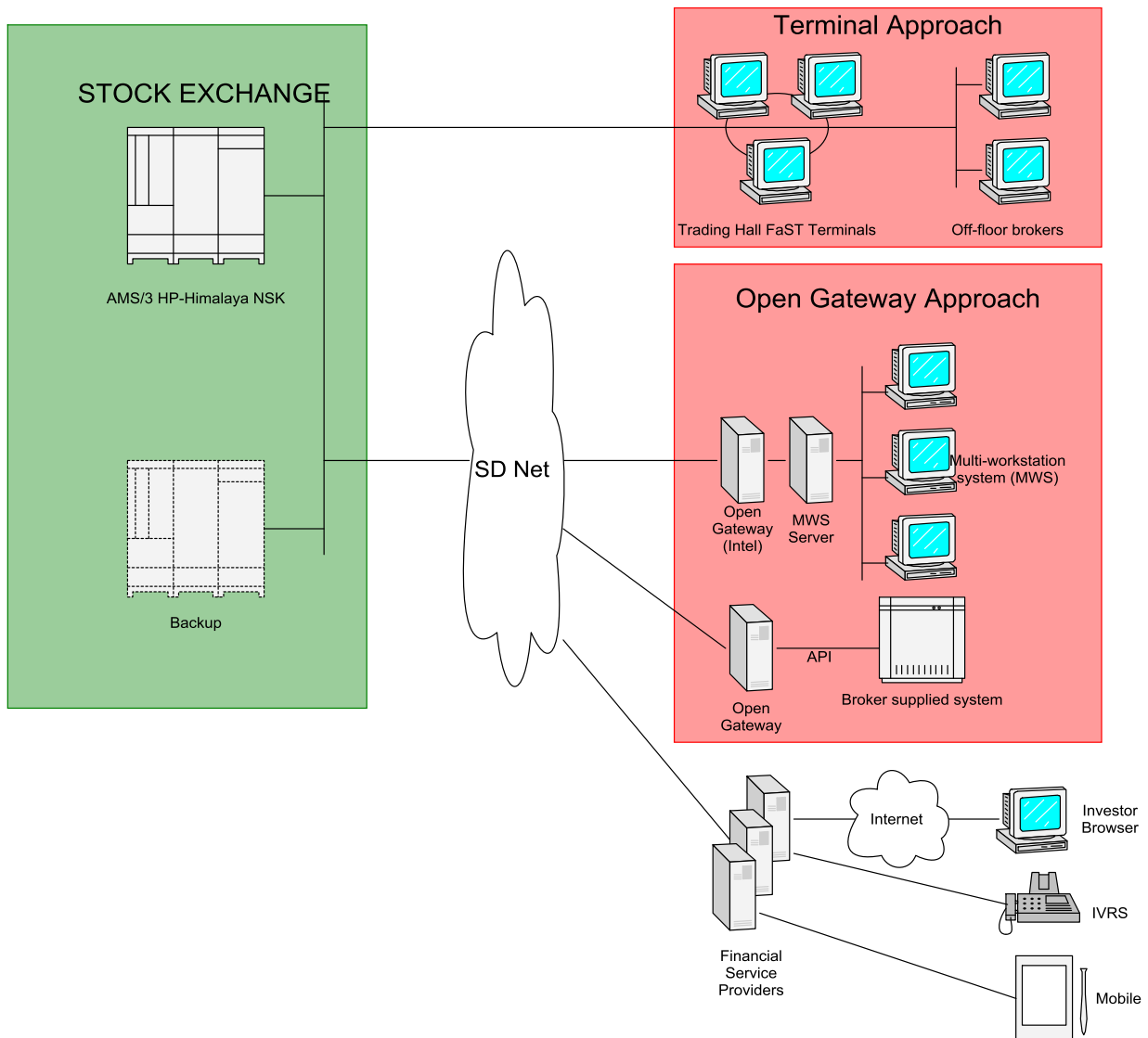


Figure 10 : HKEx AMS/3 Equities Trading System

11.1.2. Trading - future and options

In June 2000, open outcry trading at HKFE was replaced by HKATS (HK Futures Automated Trading System). This is on OMX's CLICK product, implemented on HP Alpha OpenVMS.

Participant firms have the capability to provide full electronic order routing, straight-through trade processing and other value-added services to their clients. Brokers can supply detailed information such as the exact time of order placement and execution to their clients.

HKATS also provides data on traded price and quantity ; day high/low ; and turnover. Market depth information is an added advantage for users seeking to gauge market dynamics.

An OAPI is an API for participants to integrate their in-house computer systems with HKATS. OAPI enables users to develop applications such as automatic order execution and straight-through trading.

It also allows the integration of trading systems and back-office systems for theoretical pricing, risk management, portfolio and order management.

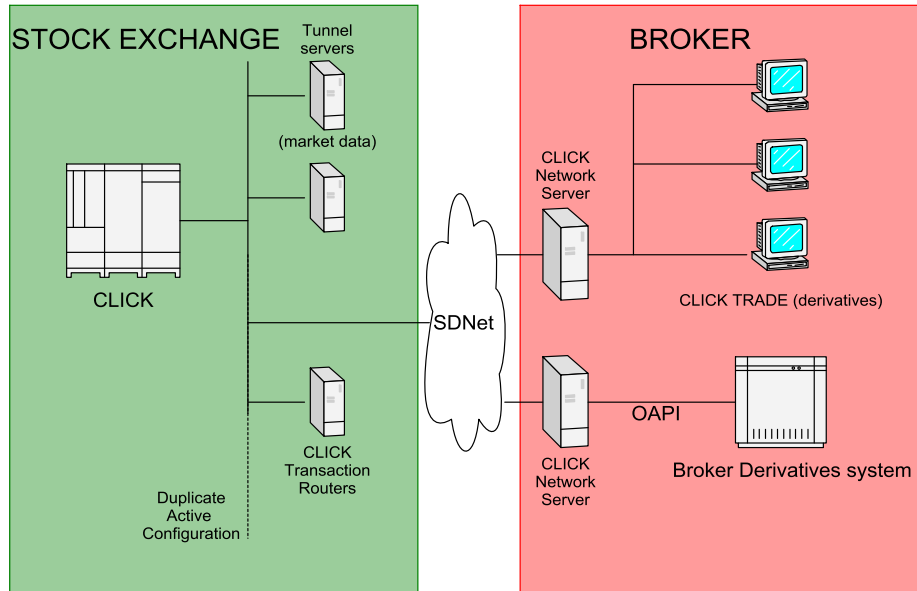


Figure 11 : HKATS connections

11.1.3. Clearing and settlement

Stocks in Hong Kong are certificated but largely immobilised and settled by book entry, although physical withdrawals of certificates are available. The longer-term aim is to move to a scripless market.

Cash market trades are cleared and settled using CCASS (Central Clearing And Settlement System). CCASS/3 is the latest version and went live at the end of 2002. CCASS/3 is a bespoke solution based on IBM z/9 host mainframe with a middle-tier subsystem based on Sun Microsystems.

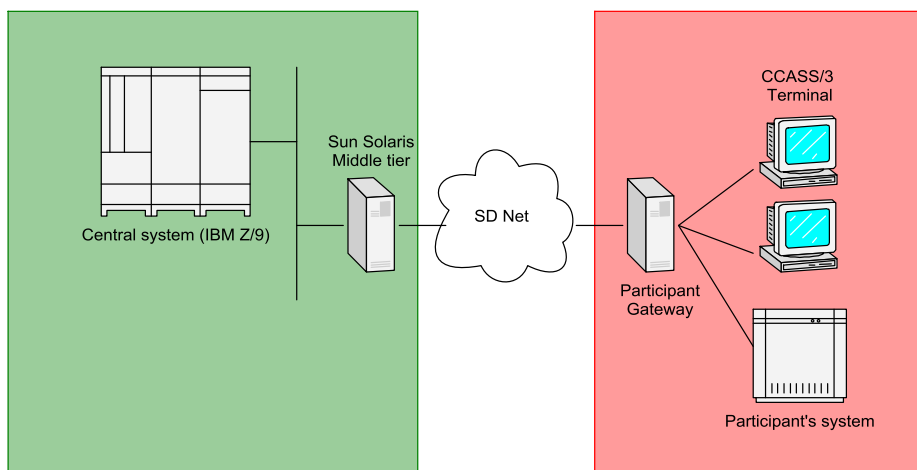


Figure 12 : CCASS/3 architecture

Important features of CCASS/3 are common risk and collateral management modules for both cash and derivatives trades.



The user front-end consists of a CCASS/3 browser-based terminal or participant gateway communicating over SDNet, the consolidated TCP/IP network for all HKEx market systems.

The middle-tier includes application and security servers, and a reporting database, facilitating enquiries and report downloads directly by the participants.

Technical architecture is built around the principles of open connectivity, thin client architecture (no business logic in front end), industry standard message and data formats, and de-coupled sub-systems. The end-to-end architecture incorporates central security control, 128-bit SSL encryption, smart-card authentication, load balancing, redundancy and disaster recovery, and scalability.

The CCASS/3 systems are supported and maintained by HKEx Information Technology Division in-house.

Futures and options are cleared and settled using DCASS (Derivatives Clearing and Settlement System). This is an implementation of OMX's SECUR system, implemented on HP Alpha OpenVMS.

11.1.4. Market data

The cash market data is distributed by an in-house system, called Market Datafeed Systems, which runs on HP/NonStop platform interoperable seamlessly with its AMS/3 cash trading system. There is a separate system for distribution of derivatives market data which runs on HP Alpha Open VMS. Both markets data feeds systems are supported and maintained by HKEx in-house.

11.2. HKEx's view on cash and derivative consolidation

HKEX were not a single entity when the derivative markets went electronic, thus they were faced with the possibility of trying to merge the systems together or keep them separate. They performed a study in 2000 surveying their members. They decided not to merge their market systems into one single system for the following reasons :

Although they have 427 participants in the cash markets and 125 derivative members, (and some 49 data vendors) all of whom are a subset of the cash markets, it was discovered that most of their members had separate systems for cash and trading derivatives.

The HKEX is a very high volume market in both equities and derivatives. Merging the cash and derivative markets systems would present a significant implementation effort and high operational risk, also (assuming it is a merger onto one of the existing systems) would reduce the performance capability of that system.

The migration off one technology platform and onto another would be a lengthy project and cost the HKEX and their members a significant amount of money, which would not be commensurate with the benefits it would bring.

The HKEX did, however, recognise that there were significant cost savings and efficiency to be made in the consolidation and integration of its network infrastructure. The markets used completely different connections using different Telcos. This was completely rationalised using a single TCP-IP connection realising a 30 % saving, some HKD20m per annum.

HKEx's technology strategy reflects their desire to support and maintain existing systems, and concentrate on running the HKEx business and the Hong Kong financial market rather than pursuing



technology business. They (for the time being) do not regard technology as a core business objective, but utilise the best of breeds technology for new system implementations and capacity expansion.

The HKEx recognise that for smaller Exchanges, running all markets on a single system might be an optimum model, compromising capacity and performance.

They do cross-collateralise between equities and derivatives markets even though the clearing systems are different. This is performed by an application which sits in between the two systems CCASS and DCASS called the Common Risk and Collateral Management System.



12. Case Study 5 : Korean Exchange

Korea Exchange (KRX) was created through the integration of the three existing Korean spot & futures Exchanges (Korea Stock Exchange, Korea Futures Exchange & KOSDAQ) under the Korea Stock & Futures Exchange Act. The securities and futures markets of former Exchanges are now operated as the business divisions of the KRX : the Stock Market Division, KOSDAQ Market Division and Futures Market Division. At the end of 2005, it was ranked 15th in terms of market capitalization and 9th in terms of trading value among the member Exchanges of the World Exchange Federation.

KRX is the largest derivatives Exchange in the world (by transactional volume).

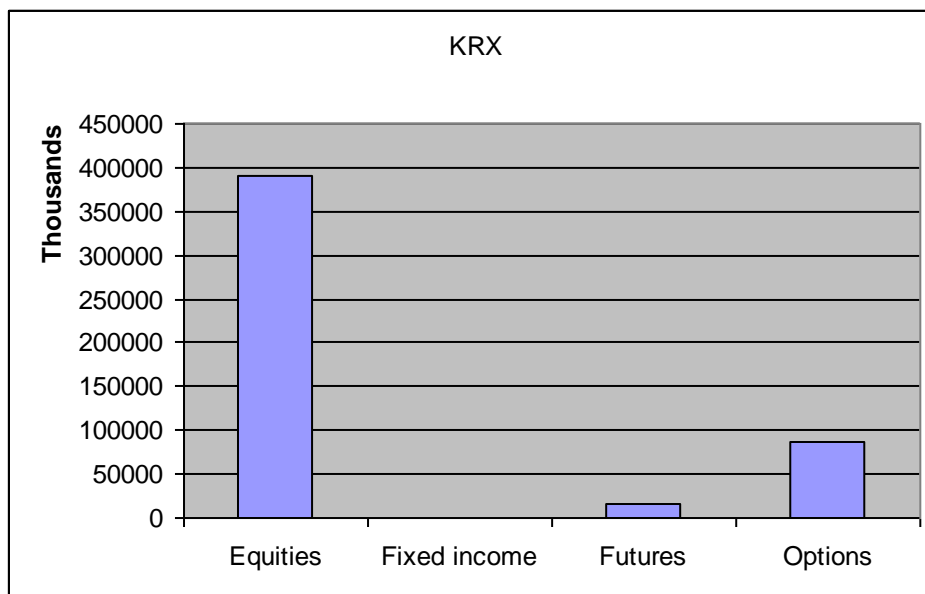


Figure 13 : HKEX Trade Volumes 2005 (WFE)

12.1. Merger of markets and the ISP project.

Korea had separate equities (including a separate growth market), bonds and derivatives markets which merged into a single entity, KRX. In 2005 they launched a project called ISP (Information Strategic Planning) which focused on establishing information Strategy Plan to efficiently support the aims and strategy of the consolidated KRX business and build a next generation infrastructure and enterprise architecture commensurate with the market vision and requirements. The IT vision was to build a global KRX premier capital market in North-East Asia. The Next-Gen architecture is described in section 12.3.

The consolidation of the considerable number of systems used in the KRX, many of which are legacy mainframe systems, will bring up to 30 % cost savings to the overall operation of the markets (assuming no increase in current operational costs).

12.2. Technical overview of the KRX trading systems – pre consolidation.

12.2.1. Equities, fixed income and repo markets (formerly the Korean Stock Exchange)

The main board market runs a trading system written in COBOL on a Unisys Mainframe on UNIX. The front end processing is based on Stratus Continuum mainframes talking to brokers via x25 circuits. Market Data is disseminated via separate UDP connections.

The KATS system is also integrated with the repo and bonds trading system KBTS (KRX Bond Trading System) which was developed in “C”, and runs on a HP-UX front end processor, communicating to brokers via either on-site gateways or the internet. It uses a local OLTP middleware product called TMAX. Market Data is disseminated by screens via the internet. This was implemented in 1996.

Market Data is disseminated via 2x 512k x25 leased lines, driven by a system written in C, TAL and COBOL implemented on HP-Himalaya. This was also implemented in 1988.

The systems are maintained by KOSCOM, a separate IT organisation dedicated to the development and support of the Stock Exchange’s systems (see section 12.3).

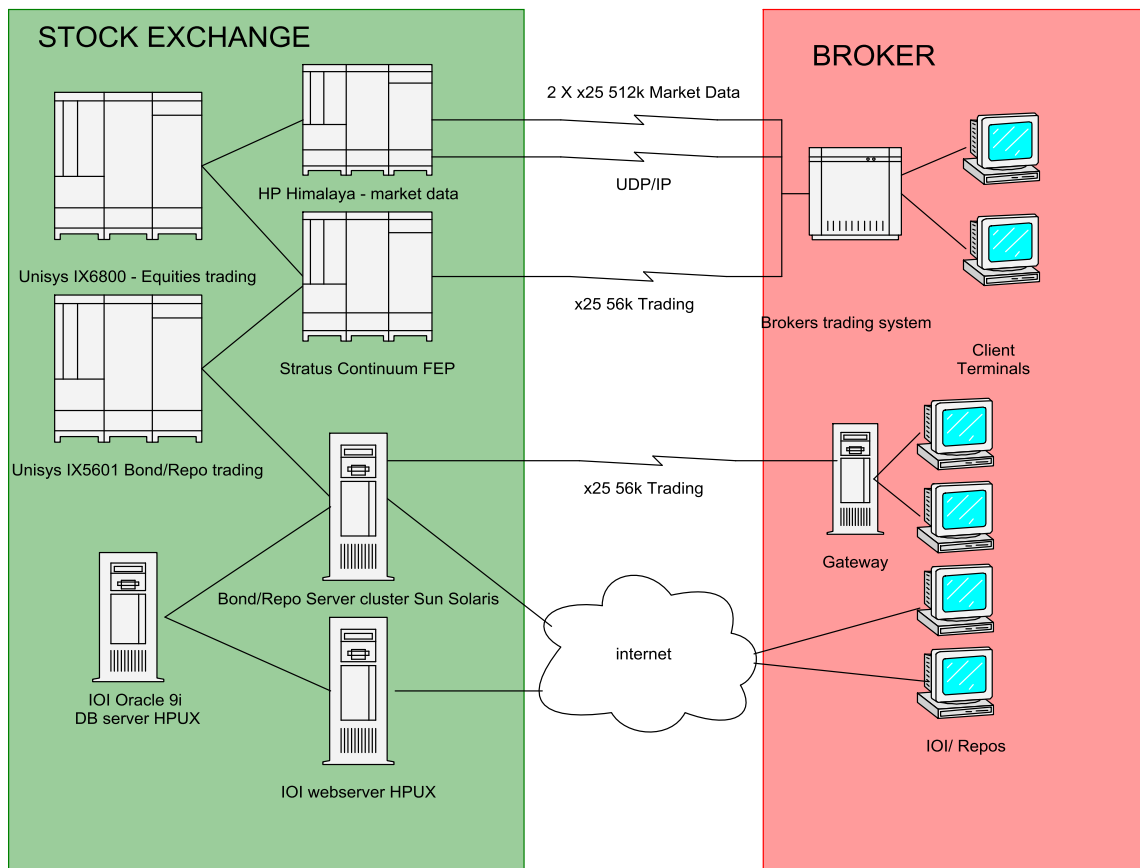


Figure 14 : Korea Stock Exchange Equities, Repos IOI systems (simplified).

12.2.2. Equities – growth market (formerly KOSDAQ)

The KETRA trading system was another in-house developed system developed in COBOL and running on HP-Himalaya. It was implemented in 1996. It is currently maintained by KOSCOM.



The system uses HP Himalaya (formerly Tandem computers). They act as a front-end processor dealing with communications, while three back end servers handle the trading engines. Stocks are split amongst three servers.

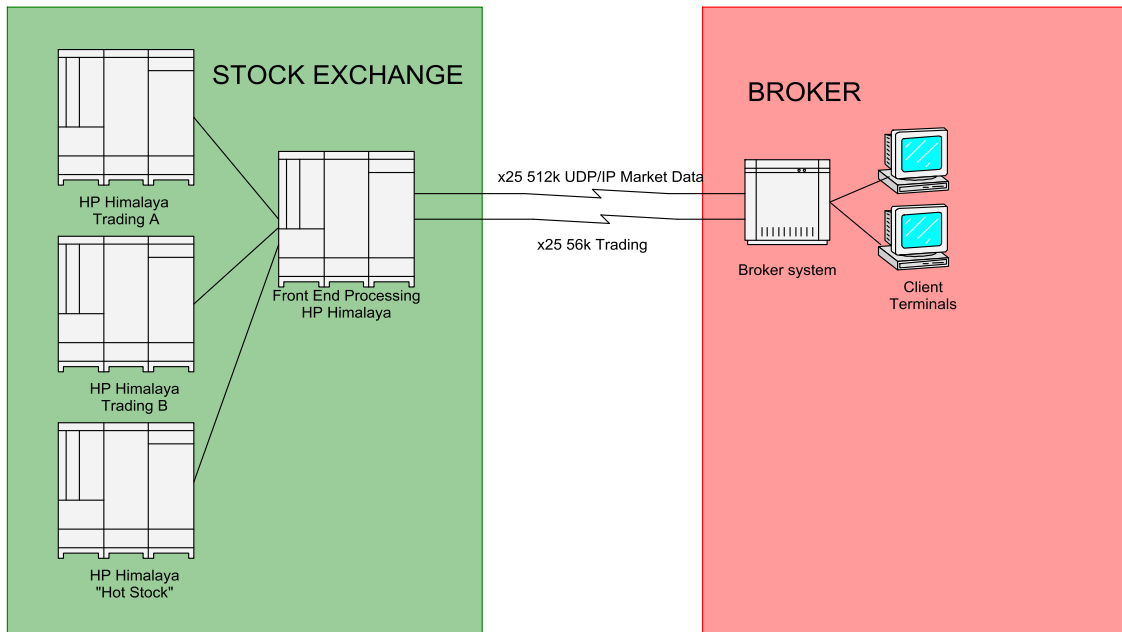
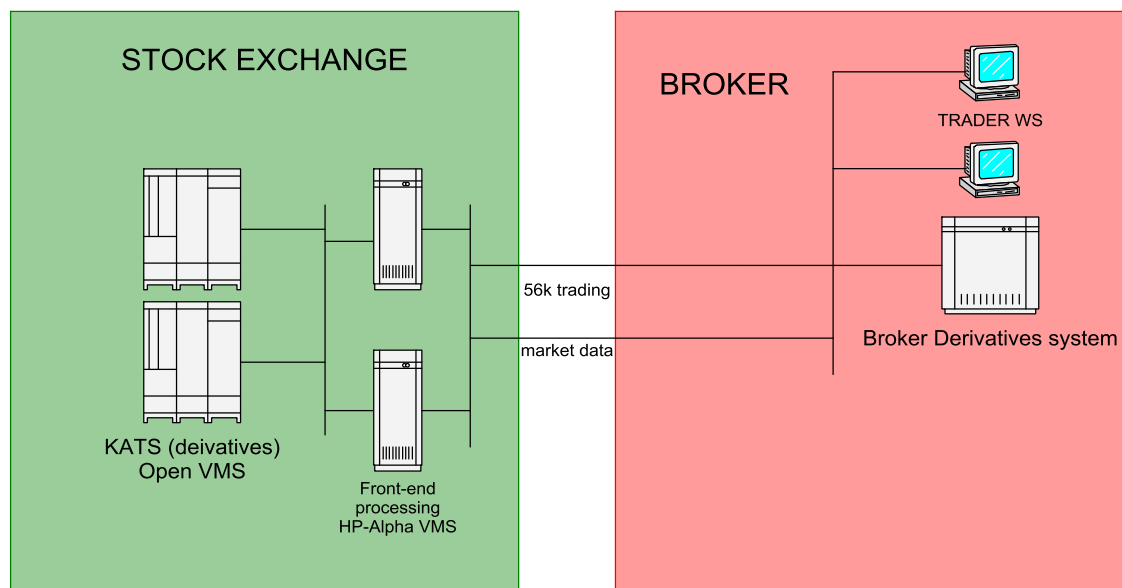


Figure 15 : KOSDAQ systems (simplified)

12.2.3. Derivatives markets (formerly KOFEX)

This was another in-house development called KATS- Futures and Options trading system. It was written in COBOL and implemented on HP-OpenVMS. It also uses a middleware product from HP called RTR (Reliable Transaction Router), Oracle 9i RDB and communicates to members via 56K X25 connections, with a separate channel for market data. The system was implemented in 1996. In 2007 it was further enhanced to accommodate the fixed income and Commodities markets.





12.3. The Next-Gen Architecture

KRX are in the process of implementing a consolidated set of systems to rationalise the different markets which they support. They are taking a strategic approach, taking in the requirements of the different markets, learning from the directions of technology and of other Stock Exchanges, and five core principles.

The core principals are :

- 1) Efficiency
- 2) Flexibility
- 3) Stability
- 4) Service
- 5) Commercialisation

The principle of the architecture is that the core areas of Front-end processing, matching, Clearing (and settlement), Surveillance, Information services and Listing disclosure, which are common to all of the most of the markets, are centralised and shared, bringing economies of scale and significant system rationalisation. There will be a common operational database and an integrated data warehouse.

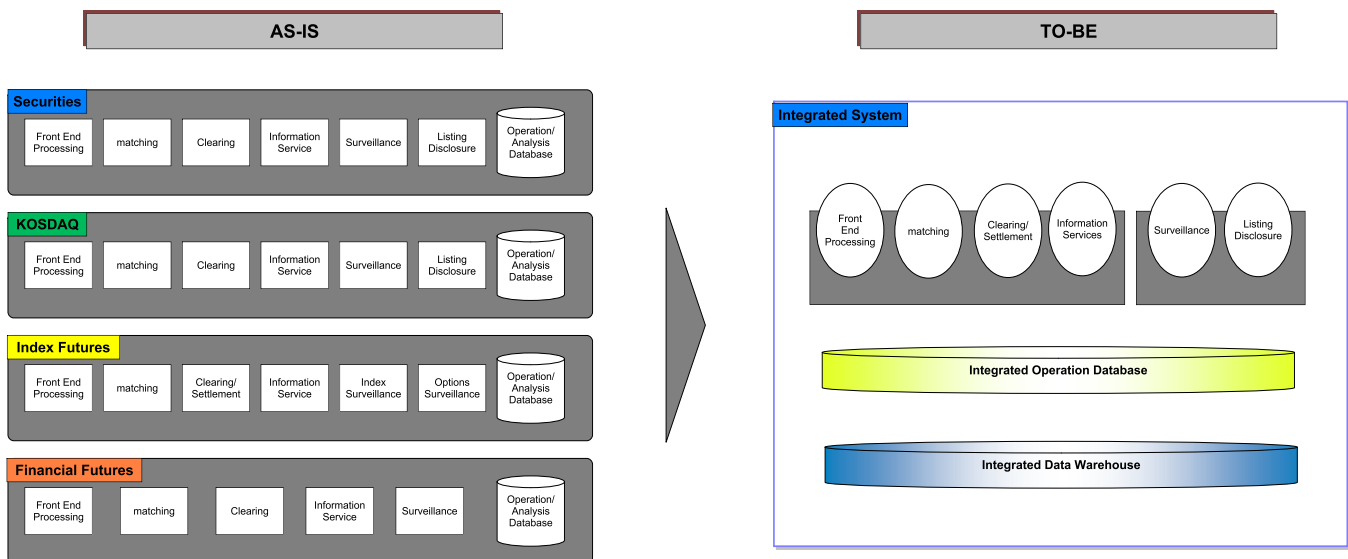


Figure 16 : KRX Next-Gen Architecture View⁴

This initiative was started in 2005 and has two main phases, being a pilot program and the main project. The pilot project is a way of establishing a proof-of concept, due to be completed by January 2008. It is envisaged that the main project will not be completed until 2009.

The KRX and its constituent Exchanges have largely adopted a policy of developing systems bespoke. They have KOSCOM at their disposal, which along with IBM, are providing development expertise. KOSCOM was originally set up in 1977 by the ministry of finance as an organisation to computerise the security markets, and today provides IT services to the KRX and to its Member firms,

⁴ Courtesy of the KRX



operates data dissemination services and provides other IT services to industry in general. KOSCOM also install, maintain and support the datacoms connections to the KRX.

12.3.1. System architecture

All components are written in C on UNIX.

The systems themselves will use standard middleware and database products on UNIX supporting hardware. The proof-of-concept project will test and either approve or eliminate some of the short listed products.

Summary of contenders for system components :

Item	Product
Overall Methodology	Information Engineering Methodology
Transaction Processing Monitor	EMS
Messaging Orientated Middleware	TIBCO
Database	Oracle, DB2, Sybase
Hardware	IBM, HP, Sun

The system itself will be based on three-tier architecture, being in three main areas of :

Access for interface handling

- 1) Middle tier for message routing.
- 2) Business tier for information processing.

The eventual technical architecture may look something like the structure shown in Figure 16, although details of this diagram may change as a result of future development and refinement.

The member interfaces will be standard TCP-IP connections at varying bandwidths depending on the number of markets and services the member requires. Current estimates are that for the Equities markets a member will require an E1 connection, for the derivatives markets 68k is sufficient.

KRX aim to develop a world-class trading environment in terms of performance and scalability with the following metrics :

Performance and scalability

- Target performance (a symbol or series of symbols) 200 TPS
- Target Performance (whole systems) 3000 TPS
- Target latency time 0.01sec

Reliability and availability

- Fail-over time : Instantaneous
- Disaster recovery : 2 hours.

Functionality

- Design for complete IT solution for capital markets to cover equity, bonds, derivatives, and warrants with order driven, quote driven and hybrid markets.

- Modular system with open architecture which provides industrial strength reliability, performance and scalability, compatible with international standard communications protocols.
- Accommodate all required functionality and flexible interfaces to trading engine, price dissemination and index calculation.

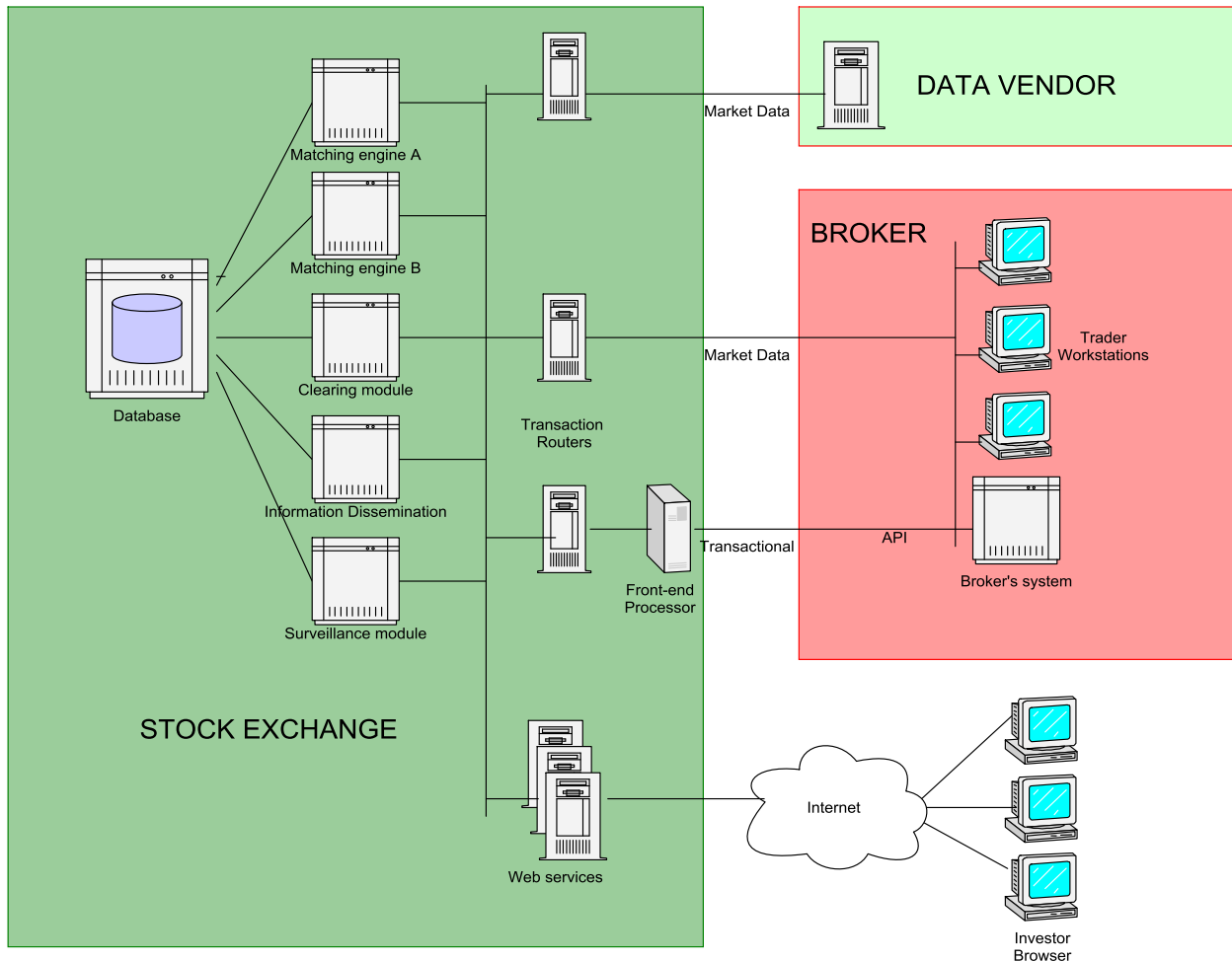


Figure 17 : NextGen architecture (Simplified without DR or redundancy)



13. Case Study 6 : NYSE Euronext

Now an integral part of NYSE Euronext since April 2007, Euronext is a pan-European Stock Exchange incorporated in the Netherlands, operating markets France, The Netherlands, Belgium, Portugal and the United Kingdom (Liffe derivatives market). In addition to equities and derivatives markets, the Euronext group is actively involved in information services. As of January 31, 2007 the companies listed on markets run by Euronext in Europe had a market capitalization of USD\$4.22 trillion, making it the 3rd largest Exchange on the planet (behind the NYSE Group of which it is a part and the Tokyo Stock Exchange). The NYSE Group is currently the first transatlantic market operator, developing links and alliances with key markets in all parts of the world.

Euronext was formed on September 22, 2000 in a merger of Amsterdam Exchanges, Brussels Exchanges, and Paris Bourse, in order to take advantage of the harmonization of the European Union financial markets. In December 2001 Euronext acquired the shares of the London International Financial Futures and Options Exchange (LIFFE), which now governs the derivative activities of Euronext in all European markets. Beginning in early 2003, all derivatives products traded on its affiliated Exchanges trade on LIFFE.CONNECT, LIFFE's electronic trading platform. In 2002 the group acquired Bolsa de Valores de Lisboa, renamed Euronext Lisbon.

All of the technology which supports the Euronext markets are operated by Atos Euronext Markets Solutions (AEMS). AEMS is a 50-50 joint venture between Euronext and Atos Origin. AEMS sell Exchange systems, products and services to the rest of the Exchanges industry and financial services as a whole. The NYSE Euronext Group recently negotiated the repurchase of Atos Origin shares in AEMS.

The merger of NYSE and Euronext will result in a combined technical infrastructure, currently devised. It will be based on the current trading systems used in the US and in Europe, allowing for the hybrid character of trading on NYSE. To date, Euronext runs different systems for trading cash and derivatives. This study explains the evolution of the technical structure at Euronext and explains the reasons for the separation of the systems.

13.1. Evolution of the systems at Euronext

13.1.1. History of NSC and Connect

The Societe des Bourses Francaises (SBF) required an electronic trading system and bought, then developed the CATS trading system from the Toronto Stock Exchange. This was implemented in 1996 as the "Nouveau Systeme de Cotation" or NSC system. Derivatives functionality was added to NSC to support the derivatives market in Paris in 1998. The same year SBF merged with futures Exchange MATIF and the options Exchange MONEP to form Paris Bourse and all trading was migrated to NSC.

The NSC system was then further developed and sold to many other Stock Exchanges, some of which traded equities, and some of which traded derivatives, notably the Globex system at the Chicago Mercantile Exchange, for which it did a technology swap for the Clearing 21 application.

In 2000 the European markets of Belgium, The Netherlands and France merged to form Euronext, followed by Portugal in 2002. NSC supported trading of all cash and derivatives on these markets except the Netherlands which continued to use an in-house system called SWITCH.

The London International Financial Futures Exchange (LIFFE) developed its own derivatives systems after abandoning its floor-based policy in 1998 by losing significant market share in Bund contracts to



Eurex. The LIFFE Connect system was launched in 1999, and was subsequently sold to TIFFE in Japan in 2001, then to the CBOT in 2003.

13.1.2. Merger of LIFFE and Euronext

Following intensive bidding, Euronext acquired LIFFE in 2002. The combined entities were then faced with the choice as to merge the supporting technologies or not. The possible outcomes would have been :

- 1) Merge all trading onto NSC.
- 2) Develop equities trading functionality onto LIFFE Connect and merge Euronext cash business onto that.
- 3) Move the derivatives trading onto Connect but not merge platforms.
- 4) Keep separate systems with Euronext derivatives remaining on NSC.

The decision to merge the derivatives trading onto LIFFE Connect, but to keep cash trading on NSC was influenced by the following factors :

- The Netherlands had not been merged onto NSC at the time of the LIFFE/Euronext tie-up and thus could be merged onto either NSC or LIFFE connect.
- Derivatives traders tended to be more international, thus most of the ones trading on the Paris and Brussels markets were also trading on London already. This meant that there was significant benefit to members to only have one system to trade on.
- Most participants had separate systems for trading cash and derivatives.
- Not many of the participants on the Euronext cash markets were trading derivatives on LIFFE, thus ruling out the possibility of a merging the cash business onto the LIFFE connect platform.
- LIFFE and AEMS (then called Atos Euronext) had to man support operations for other installed instances of Connect and NSC respectively, including it being run as an ASP offering in the case of CBOT (LIFFE) and SIMEX (NSC). Thus there would not have been significant savings in reduced operational overheads.
- Both are high volume markets, and the separation of systems reduces operational risk.
- A large part of the value of LIFFE was attributed to the connect system.

The derivative trading was migrated from NSC to LIFFE Connect in just six months in 2003. This process was a great deal easier than comparable Exchange migration projects simply because many of the derivative participants traded internationally and thus already had connections to both systems. The Dutch derivatives markets were migrated from SWITCH to LIFFE in 2004.

13.2. Technology at Euronext.Liffe

13.2.1. Cash

The NSC system is actually a suite of products that communicate using a common messaging middleware called MMTP. The sub-systems are :

- ❑ TCS – Trade Reporting Engine – handles outsized or block trades
- ❑ ECO – Market Control computing module – handles aspects of the derivatives markets
- ❑ PFI – handles index calculations
- ❑ SPI and IRIS – market surveillance application
- ❑ DIFF – market data broadcasting module



- NSC – the central transaction-processing engine.

All of these units communicate through a central hub, which ensures timely delivery of messages and fairness when using a multi-module configuration. The hub configuration also allows many Exchanges to have links between themselves, enabling cross border trading. The modules may run on the same physical hardware, or may be on separate machines in order to reserve processing power for the main trading engine.

The systems communicate to member firms through CAP for or MAP servers. These can be on customer's sites or at Euronext's facilities.

The core systems have recently been migrated to LINUX, but were originally developed on HP-Himalaya. The communication links to a client site are via 256K lines, according to the services subscribed to. Market Data may also be broadcast using satellite technology to reduce line costs.

The MMTP sub-system runs entirely on TCP-IP.

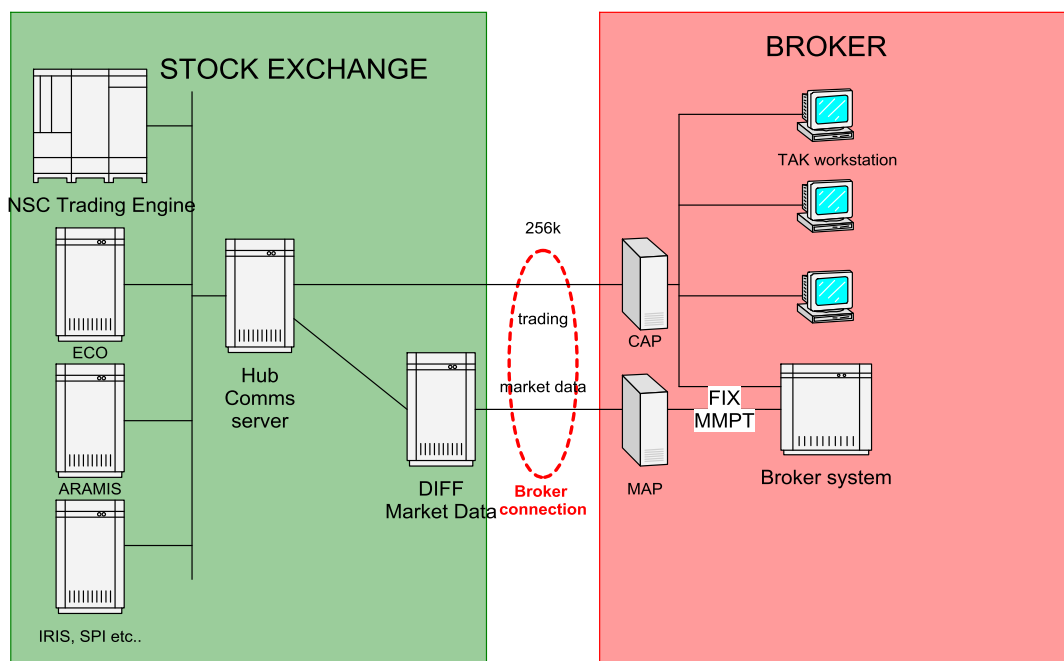


Figure 18 : The NSC system from AEMS

13.2.2. Derivatives

LIFFE Connect is a specific derivatives system. It is based on Sun Solaris, being largely a single top of the range Sun Fire F15K server with distribution hubs and customer-sited gateways. Euronext.LIFFE originally decided to use Sun servers as it had already developed a system to support the open outcry market called Automated Pit Trading (APT).

A public specific API for LIFFE Connect then communicates to a broker's in-house system or to third party products licensed to access the markets. Euronext.LIFFE does not supply a trader workplace.

Internal messaging is accomplished using a proprietary messaging middleware developed by Euronext, being an interactive service called RTC (Reliable TCP) and market data broadcast via RMC (Reliable Multicast Protocol), which uses a combination of UDP-IP and TCP-IP. The F15K server is backed up for warm failover, managed by LDAP.

LIFFE.Connect does not incorporate specific resiliency modules or messaging middleware, or multiple servers processing in step with each other. The central F15K servers are considered to be sufficiently

reliable in order to meet their strict service level agreements. The use of a single server decreases the amount of messaging. As such the Sun server is able to process complex orders and matching at significantly higher levels than other Exchange solutions.

A separate Oracle database allows much of the storage of persistent information from end of day to start of day and the importing of static data and external prices from other markets. A separate Intel-based application using Microsoft SQL server audits order messages and enables monitoring and control of the markets and replaying of events for Market supervision.

Functionally, the LIFFE connect system contains some of the richest derivatives processing of any system. It is able to handle various straddles and strategies, and is also able to handle implied orders across different (Euronext) markets. Multiple order matching algorithms are also available, configurable by commodity.

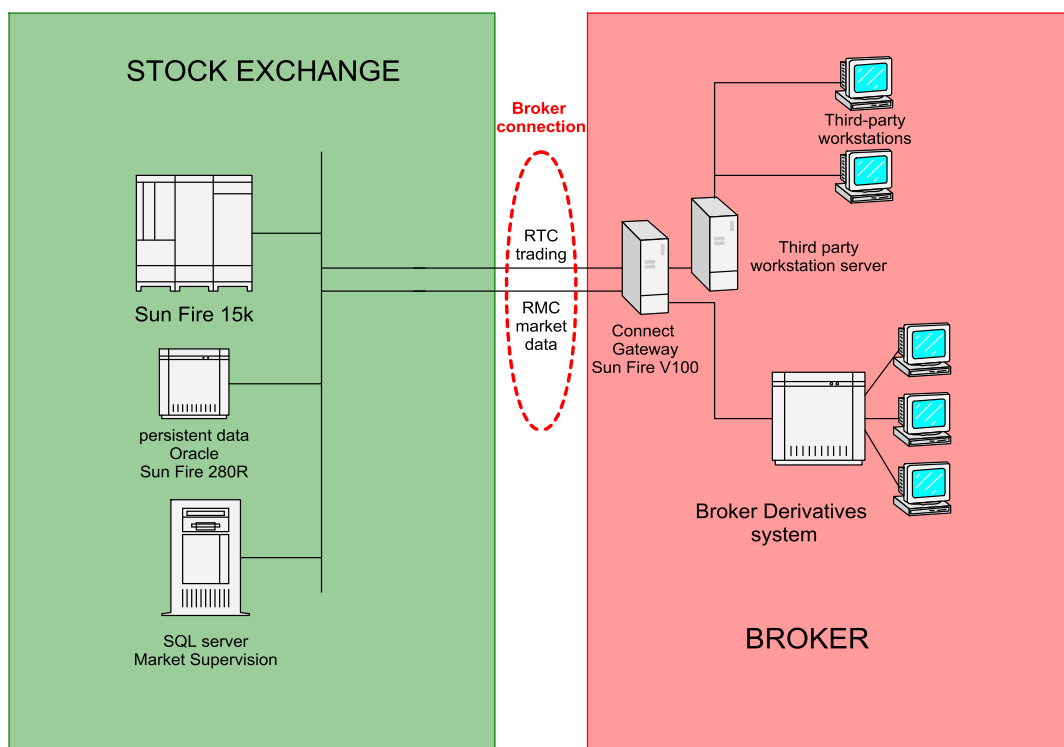


Figure 19 : LIFFE.Connect

13.3. NYSE Euronext's IT strategy going forward

AEMS is in the process of redeveloping the NSC and Connect systems, which hitherto have had vastly different architectures, into a single product set. The first stage of this was to unify the operating systems onto LINUX, which is rapidly becoming the server-side industry standard. In tests, the Connect system's throughput has been doubled through this migration.

Access to markets is also now available through FIX 4.2 for cash and 4.4 for derivatives trading.

14. Case Study 7 : OMX

OMX started a Swedish derivative Exchange in 1985 and was the world's first publicly listed Exchange in 1987. Today OMX has three primary divisions : The Nordic Marketplaces, Information Services & New Markets and Market Technology.

The OMX Nordic Exchange provides listing, trading and clearing of securities for more than 80 percent of the Exchange trading in the Nordic and Baltic countries. The Market Technology provides trading, clearing and settlement systems to more than 60 customers in 50 countries.

The Market Technology division supports a number of the trading systems detailed in this report, including the CLICK XT, Horizon, SAXESS and X-stream trading systems.

OMX have now merged with NASDAQ, forming NASDAQ OMX Group, however the study concentrates on OMX pre-merger, especially in respect of their home markets.

14.1. Technical environment at OMX

14.1.1. Equities

The equities markets are run on the SAXESS trading system for the Swedish, Norwegian, Danish, Icelandic, Finnish, Lithuanian, and Estonian and Latvian markets.

The SAXESS system was originally developed by the Stockholm Stock Exchange (Stockholmboersen) and implemented in 1999. It was developed internally, and runs principally on Sun/Solaris with Linux

The configuration of the system is a front-end-back-end three tiered system. The back end actually hosts the order book and manages all transactions, the front ends deal with (multiple) client connectivity, recovery and general statefulness of the system. Both back end and front end servers are replicated on secondary sites to operate in a fully resilient manner.

A separate market data distribution platform called "TARGIN", also on Sun Solaris, manages data distribution and failure recovery for data vendors and brokers systems which require full market depth.

The systems were developed in C and use an Oracle Database in the backend server (although processing of the order book is held in memory).

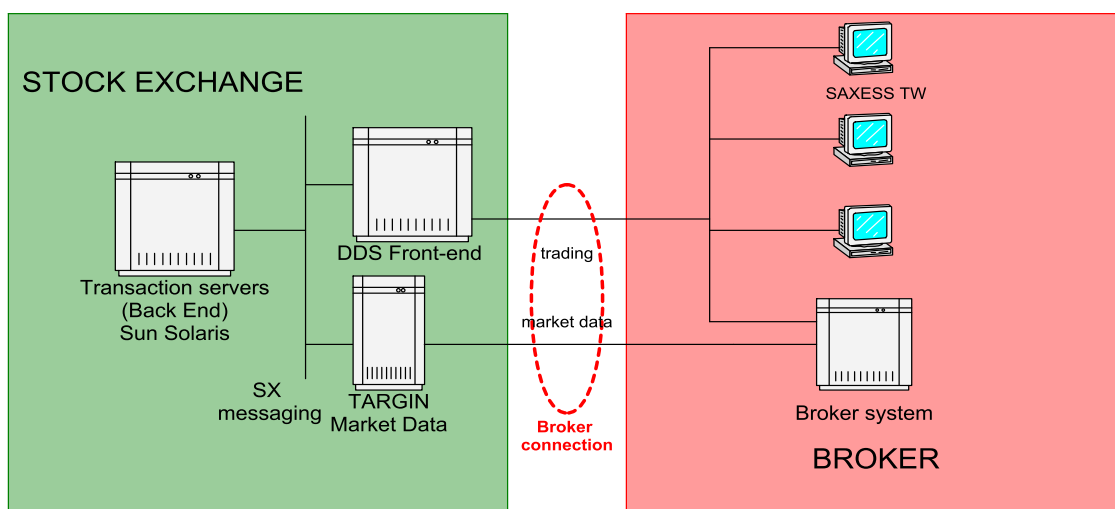


Figure 20 : The SAXESS system from OMX



14.1.2. Derivatives

The CLICK XT system supports derivatives trading for the Nordic Markets.

CLICK XT is an electronic marketplace system composed of modular subsystems. The backbone of the CLICK XT system is OMnet, a general and powerful communication system that supplies the participant with an open public interface to the central functions. The OMnet API is supported by more than 35 leading Independent Software Vendors (ISVs).

CLICK XT Technical facts :

- Operating system (CPU) : Open VMS (Alpha and Itanium) and Linux (Intel).
- Database : Oracle.
- Transaction Infrastructure : RTR (HP Reliable Transaction Router).

CLICK is the world's leading Exchange system, having been sold into the markets of the American Stock Exchange (AMEX), Athens Stock Exchange, Australian Securities Exchange (ASX), ICAP, the California Power Exchange, Copenhagen Stock Exchange, EDX London, Hong Kong Exchanges and Clearing, International Securities Exchange (ISE), KRX, Borsa D'Italia (IDEM Market), Singapore Exchange (SGX), Thailand Futures Exchange, the Toronto Stock Exchange and the Vienna Stock Exchange.

CLICK XT has added support for integrated trading (cash equities and derivatives) and is currently used by the ASX and SGX for integrated trading.

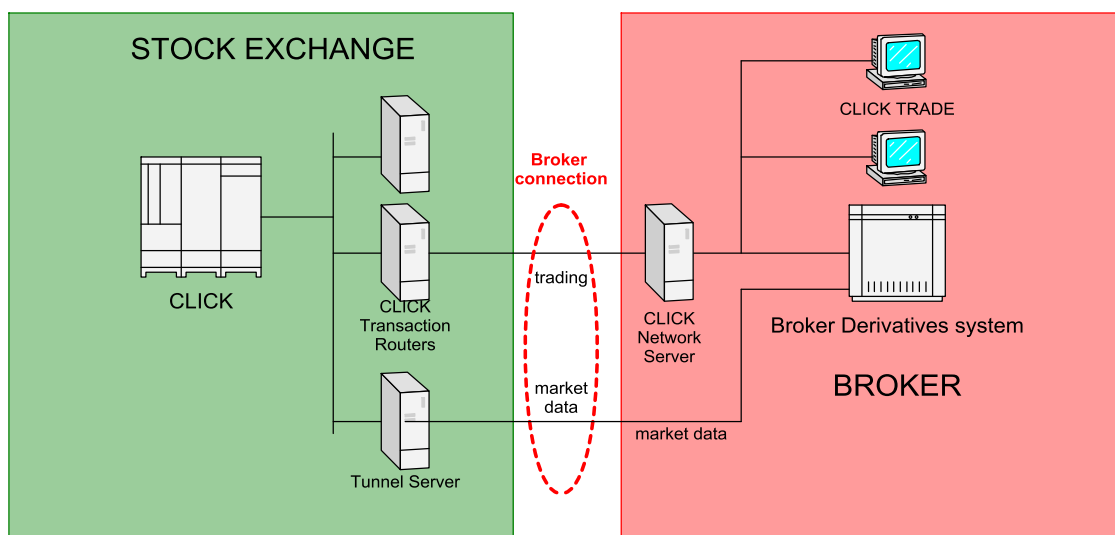


Figure 21 : CLICK in Stockholm (simplified)

14.2. The evolution of separate systems at OMX

NASDAQ OMX is currently the worlds leading supplier of Stock Exchange systems. Both the CLICK and X-stream systems are capable of supporting derivatives and equities business on the same



platform ; however, OMX as an Exchange, continue to run a separate system for cash and derivatives markets.

At the time when a new system was needed at the Stockholm Stock Exchange, the obvious choice would have been to take a version of CLICK and modify it for equities, especially with a potential merger between the two markets. However at the time, the Stockholm Stock Exchange was a mutual organisation whereas OM was a for-profit Exchange, principally owned by one person. It was thus politically not possible to take a copy of a competing organisations' system. Hence SAXESS was developed and implemented.

At the time of the acquisition of the Stockholm Stock Exchange in 1998, the technology supporting both markets had been established. OMX have not merged the technology of the cash and derivative markets for the following reasons :

- OMX have been (to date) highly occupied with the amalgamation of the Nordic Markets. The consolidation of national markets brings significant cost savings to OMX as an organisation (the merging of Helsinki in with OMX was estimated to bring a 40 % saving on IT). The drive to amalgamate the Nordic markets has, to date, outweighed the benefits that can be derived from an integrated trading platform.
- As the CLICK and SAXESS products have been sold into other markets, OMX need to keep teams to provide development, support and maintenance. OMX provide 24 hour support to their installed markets around the world. The consolidation of the cash and derivative markets in the Nordic markets would thus not bring the benefits it has in other markets.

There are 162 Exchange members at OMX.

14.2.1. Genium

NASDAQ OMX, through mergers and acquisitions of other Exchange system providers, has a product set of some seven core trading systems developed individually. Prior to the NASDAQ merger, they announced a harmonisation of their product set under an initiative called "Genium", which aims to bring the best features of their systems and unify them under a generic set of system components which will handle all trading, clearing and settlement in the same system environment. This will be rolled out at a future date across the Nordic Markets.

The Genium product set specifically aims to provide consolidated transactional systems with high performance, high availability, operating on standard hardware and using industry standard connectivity with FIX for trading and FAST for market data.



15. SGX Case study

Singapore Exchange Limited (SGX) is Asia-Pacific's first demutualised and integrated securities and derivatives Exchange.

SGX was inaugurated on 1 December 1999, following the merger of the Stock Exchange of Singapore (SES) and the Singapore International Monetary Exchange (SIMEX).

On 23 November 2000, SGX became the first Exchange in Asia-Pacific to be listed via a public offer and a private placement. Listed on the Exchange, the SGX stock is a component of benchmark indices such as the MSCI Singapore Free Index and the Straits Times Index.

Home to Singapore's leading listed companies, SGX is also at the forefront of Exchanges globally in attracting international issuers and is rapidly emerging as Asia's offshore risk management centre for international derivatives.

The SGX merged its markets in 1999, and has set about a project to merge the equities and derivatives markets onto a single unified platform. It is still in the process of effecting this change, having successfully merged the derivatives market onto the new platform. The Equities market is due to go live in Q1 2008.

This case study describes the systems prior to the consolidation and the process by which SGX are managing the migration.

15.1. Technical environment at SGX pre consolidation

15.1.1. Equities

Securities trading is handled by the Singapore Exchange Securities Order Processing System (SESOPS) which is an in-house system running on HP UX.

This was based on a bespoke solution by one of the founders of Financial Markets Computer Systems (FMCS), who were then purchased by Computershare and subsequently by OMX. The system became their X-stream product. SEOPS was implemented in 1992.

The system operates on a multi-node configuration with a main transaction processor, with other modules providing services like gateway functions, distribution of market data, market supervision etc. Brokers connect via a bespoke API to a gateway or can use trading terminals provided by SGX. The entire messaging middleware supports concurrent operation of a disaster recovery configuration which can provide hot failover.

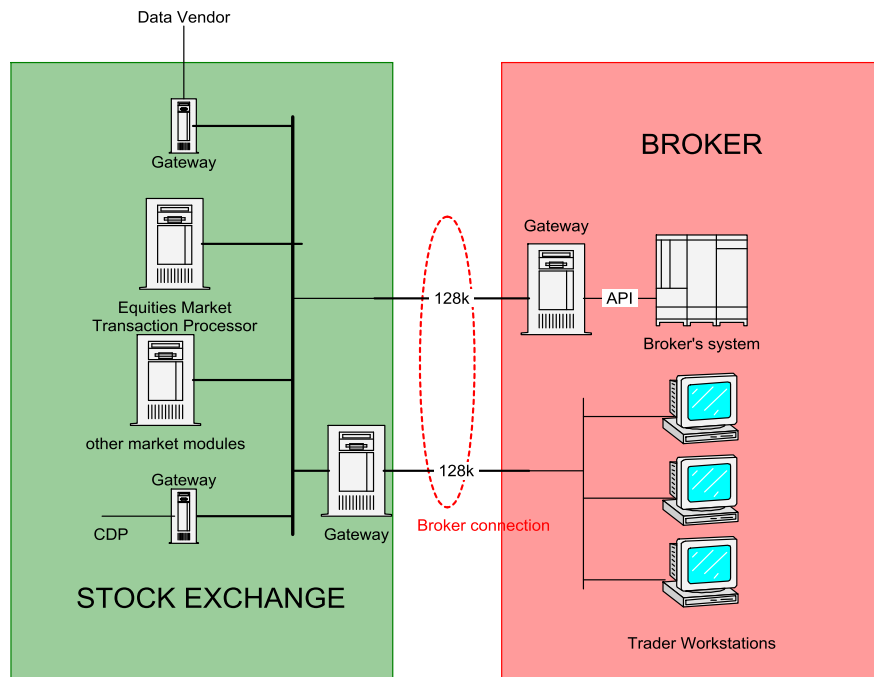


Figure 22 : The SEOPS system at SGX

15.1.2. Derivatives

The SIMEX derivatives market was supported by the NSC system from AEMS.

The NSC system is actually a suite of products that communicate using a common messaging middleware called MMTP. The sub-systems are :

- ❑ TCS – Trade Reporting Engine.
- ❑ ECO – Market Control computing module – handles aspects of the derivatives markets.
- ❑ SPI and IRIS – market surveillance application.
- ❑ DIFF – market data broadcasting module.
- ❑ NSC – the central transaction-processing engine.

All of these units communicate through a central hub, which ensures timely delivery of messages and fairness when using a multi-module configuration. The hub configuration also allows many Exchanges to have links between themselves, enabling cross border trading. The modules may run on the same physical hardware, or may be on separate machines in order to reserve processing power for the main trading engine.

The systems communicate to member firms through CAP for or MAP servers. These can be on customer's sites or at the Exchange's facilities.

The SIMEX system was run as an ASP (application service provider) remotely from AEMS's premises in Paris. It was retired in 2004 with the introduction of CLICK.

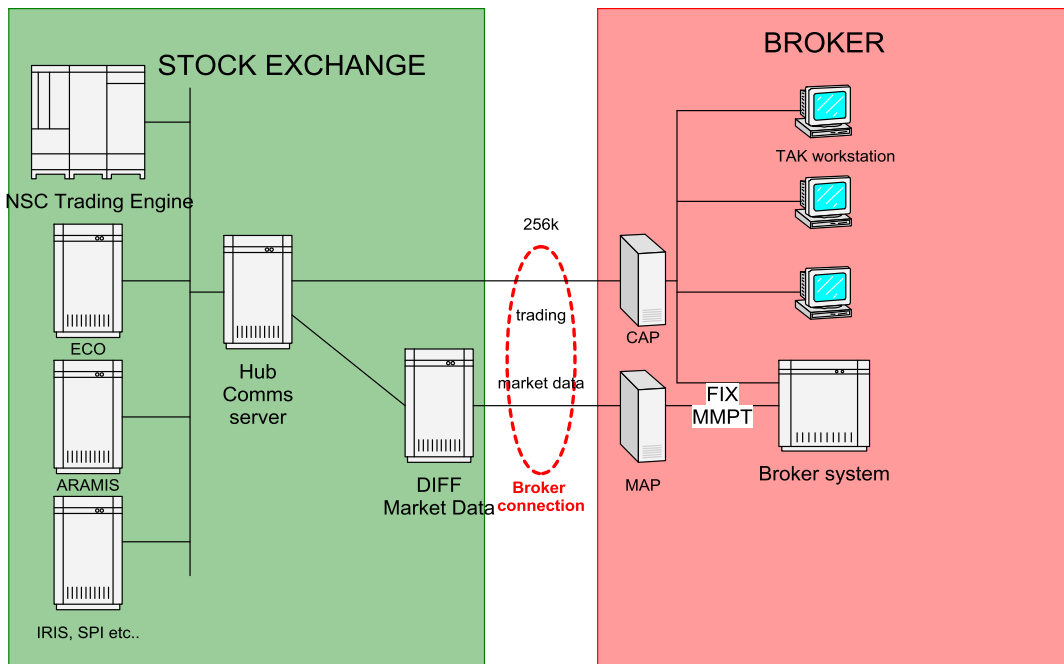


Figure 23 : The NSC system from AEMS

15.2. SGX Quotation and Execution System (SGX Quest)

Shortly after the merger between the equities and derivatives markets, the SGX commenced a study called the "IT Blue Print" aimed at rationalising the markets and facilitate the full automation of trade processing from trade execution to final settlement.

A core component of this was to merge the equities and derivatives trading onto a single platform. The reasons for this decision were as follows :

- Integrate service /access to members who want to trade both
- Allow members to do cross-asset margining
- Reduce members costs through connection rationalisation and system integration
- Reduce the operational costs at the Exchange in only needing a single environment
- Align the systems to its strategy of outsourcing system development, maintenance and operations.

The SEOPS system is a legacy in-house system requiring the SGX to support a development function. SGX have decided as a strategy to outsource as much as possible. They have already outsourced the operations of the SEOPS system to HP.

The SGX ETS system was also perceived to be an expensive overhead for the SGX to continue operating.

After a lengthy RFP process which included the providers of the existing systems, the contract to implement Quest was awarded to OMX and its CLICK-XT product. This was awarded in 2003.



15.2.1. Market migration

The Technology roadmap then set about the migration of the markets onto the new trading platform.

The strategy for the migration was to develop and implement the derivatives market first. This was accomplished in 2004.

The equities markets are higher volume, thus the market readiness project needed to allow a greater length of time for members to redevelop their systems away from the SEOPS system and retrain users on GL-Trade rather than the SGX supplied system.

There are 28 members of the derivative markets and 26 Equity market members. 17 are members of both markets. Compared to most other markets there is a significant congruence between markets.

15.2.2. Technical environment of the new trading platform

The CLICK-XT implementation will have separate derivatives and equities trading servers communicating to members through the same messaging middleware. The Quest system will standardise on FIX connections to members' systems.

The Click product set is a series of back-end server components that perform different tasks. They communicate to either a transaction router for transactions, or to "tunnel" servers for market data broadcast. These then communicate with network servers on customer's site to connect to GL-Trade workplaces or to an ISV solution or to a data vendor. The components communicate through a secure messaging subsystem called RTR (Reliable Transaction Routing) from HP (originally a Digital product).

The back end servers are HP Alpha OpenVMS. The suite of products is now also available on Sun Solaris, using Veritas in place of RTR. The gateways work on IBM RS6000 boxes. The system is developed in C.

The architecture of an amalgamated market data feed has not been decided at the time of writing.

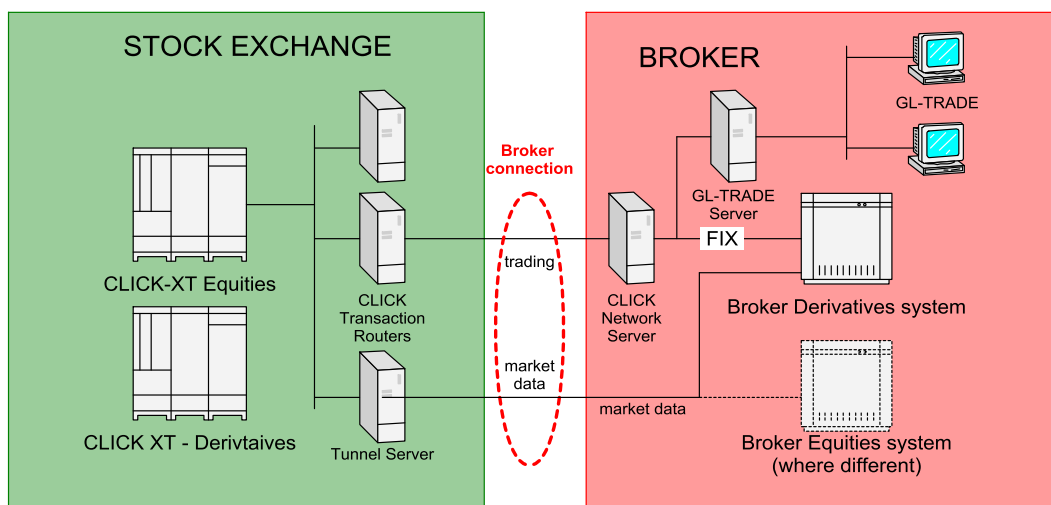


Figure 24 : IT Blueprint roadmap solution with CLICK-XT



SGX intend to outsource development and maintenance and support to OMX, recognising that they, as an Exchange, should concentrate on running the markets and not developing technology. They also have outsourced their data centre and IT operations to HP who have taken on some 50 staff members.

As SGX provided a trader workstation bespoke to SEOPS, they needed to provide a replacement for Quest. Only 3 of the equities market members use the API connection to the Exchange, the rest use the SGX front-end.

They have also outsourced this provision to GL-Trade. GL Trade is the worlds leading platform for order management, available in ASP-form, developed to support cross-asset trading on over 130 markets worldwide.

The Equities market is due to go live in 2008.



Appendix A: Functional differences between cash and derivatives systems

This list of functions are attributed to OMX's CLICK system.

A.1. Core functionality

Generally the core order matching functionality is the same between Cash and Derivatives as follows :

- Support for many separate markets, segments or Exchanges in a single system.
- Support for many different trading calendars (trading, banking, settlement and holidays).
- General order matching.
- Market Making functionality.
- Information dissemination
 - Price depths & hold-back timers for same instrument.
 - For illiquid instrument, intelligent updating, sending data immediately.
 - Configurable subscriptions down to instrument class.
- Interface to clearing and/or settlement.
- Fail-over/resiliency.
- Exchange defined corporate action and notifications (equities).
- Price deviation / circuit breaker.
- Order history server and recovery.
- Primary market auctions.

A.2. Specific to a derivatives system :

- Automatic series generation.
- Mass quotations.
- Combination orders
 - Equity-Derivative Combination orders.
 - Tailor Made combinations.
 - Bait generated even if different contract sizes are traded.
- Series rename transfer.
- Information dissemination
 - Two different price depths & hold-back timers for same instrument.
 - For illiquid instrument, intelligent updating, sending data immediately.
 - Configurable subscriptions down to instrument class.



A.3. Specific to Fixed Income :

- Repo trading functionality
 - General collateral, Special and buy/sell back Repos.
- Duration neutral switch trading
 - Basis trading, bond to bond switch.
- Settlement amount calculations & settlement amount as part of real-time STP trading confirmation message.
- Sophisticated commission calculations functionality.
- “Only best” order type.
- Hold-in market timer.
- Full support for fractions.
- Work-up.
- Passive / Aggressive order concept
 - Supports for locked market allowing / disallowing.
- Linked orders.



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