NATIS: Novel Architecture Framework for Algorithmic Trading Information Systems -- Automated Stock Trading via Electronic Communication Networks

Samuel Sambasivam, Ph.D.
ssambasivam@apu.edu

Sheldon Liang, Ph.D.
sliang@apu.edu

Computer Science Department
Azusa Pacific University
Azusa, CA 91702

Roger Liao
rliao@ix.netcom.com
Yootech Associates LLC

Abstract

Computer Information Systems (CIS) are broadly applied to many areas via internetworking computers. Among them Algorithmic Trading via Electronic Communication Networks (ECN) represents a new direction toward which CIS is applied to the stock exchange in an automated way. This paper presents a Novel Architecture Framework for Algorithmic Trading Information Systems (NATIS) with emphasis on its scalability, flexibility, and generality for Algorithmic Trading (information) systems via ECN with emphasis on such views as strategic view (activities through cognitive processes of decision-making), managerial view (activities to accomplish desired goals), and operational view (activities to produce profit) in order to support sound features: scalability, flexibility, and generality. A case study is also given to specify how NATIS flexibly accommodates Day Trading Business through strategic, managerial and operational activities in an automated way. As a result, flexibly constructing automated stock trading is made not only feasible via ECN, but also possible when trading strategies need to alter to take advantage of various situations.

Keywords: AST: Algorithmic Stock Trading, ECN: Electronic Communication Network, TAFIM: Technical Architectural Framework for Information Management.

1. INTRODUCTION

Today, Computer Information Systems are broadly applied to many areas, including Algorithmic Trading via Electronic Communication Networks, or ECN for short, which are automated order matching systems. An **Information System** (IS) is any combination of information technology and people using this technology to support operations, management, and decision-making (SEI Report). This kind of mission-specific computer information systems involves many computational activities, such as the gathering, processing, storage, distribution and use of information via internetworking computers. These activities are typically categorized as: **strategic** -- decision-making through a cognitive process that results in the selection of a course of action among several alternatives, **managerial** -- assembling parties (referring to data, information, and knowledge) together to accomplish desired goals and **operational** -- ongoing recurring activities involved in the running of a business for the purpose of producing profit.

In electronic financial markets, **algorithmic trading** or **automated trading** is the use of computer programs to enter trading orders with the computer algorithm deciding on characteristic of the order such as the timing, price, or quantity of the order and in many cases initiating the order without human intervention. Obviously, algorithmic trading via ECN represents a new direction toward which Computer Information System(s) is applied in an automated way. For instance, an example of algorithmic trading or automated trading is if a day trading request to buy or sell a stock or security is sent into ECN, the trading platform behind ECN automatically matches the order with an opposite order (i.e. a sell if it's a buy, or a buy if it's a sell) of the same size for risk-management purposes. Advantageously, for a liquid stock, an ECN can manage this in a second or less drastically reducing the probability for a high loss.

Algorithmic trading via ECN, regarded as a typical computer information system, involves information technology, and human interaction with this technology, to support operations, management, and decision-making. In a very broad sense, the term information system is frequently used to refer to the interaction between people, algorithmic processes, data and technology. In this sense, the term is used to refer not only to the information and communication technology (ICT) an organization uses, but also to the way in which people interact with this technology in support of business processes.

AFIM: A Reference Architecture Model

In order to effectively incorporate information (source data, intelligence), algorithmic process (business application), and communication technology into computer information systems, TAFIM provides us a great reference model to reflect mission-specific software architecture, data structures (architecture), and communication infrastructure, shown as Figure 1.

The Technical Architecture Framework for Information Management (TAFIM-DoD) provides enterprise-level guidance for the evolution of the DoD Technical infrastructure. It also identifies the services, standards, concepts, components, and configurations that can be used to guide the development of technical architectures that meet specific mission requirements. The entire enterprise, as previously defined, includes Work Organization, Information, Application, and Technology. This leads to the four different views:

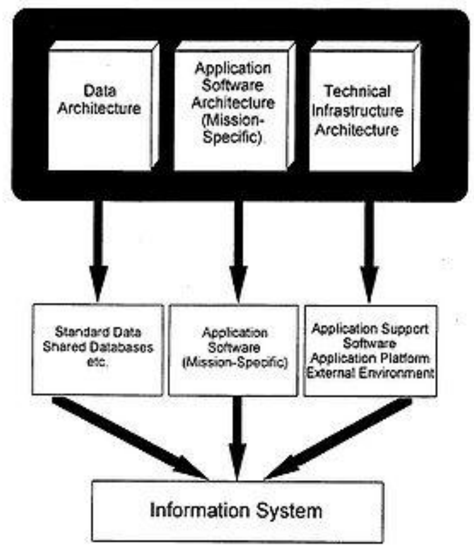

Figure 1. Technical Architectural Framework for Information Management

- *Work Organization View*: The work view of architecture is developed by identifying specific classes of users within the business environment, business location. This is the logical representation of the business functions that are required to deliver products and services.
- *Information Management View:* The information architecture of the enterprise will contain three levels of detail; subject areas, data groups, and data attributes.
- *Application View*: This view focuses on the opportunities to automate aspects of work and or the access to information needed to perform work.
- *Technology Infrastructure View*: This area of architecture uses specific component-level models to provide the basis for linking the technology view of the architecture to the work, information, and application views.

TAFIM, recommended by the US DoD as a reference model for enterprise architecture development, defines a target common conceptual framework, an information system infrastructure. However the architecture and associated model, is NOT a specific system design. Rather, it establishes a common vocabulary and defines a set of services and interfaces common to information systems.

NATIS: A Novel Architecture Model

The ideal adaption of TAFIM to NATIS (novel architecture framework for algorithmic trading information systems) is developed with emphasis on strategic computation through cognitive process, in which the decision-making mechanism should be very flexible to adjust trading strategies with great ease (Altucher, 2004). Comparatively and relatively, operational activities, embodied as input-process-output paradigm as well as information management, are sophisticatedly stable without dramatic change from application to application.

As well known, systematic scalability (what allows a system to continue to function well when its context is changed in size) and informative generality (what parameterizes data type to a generic extent in order for information management to be done in a unified way) are fundamentals of constructing complex information systems, in which we have already achieved sound accomplishments in our previous work (De Lemos, 2004; Liang, 2003a; Liang, 2003b). In constructing algorithmic trading systems, functional flexibility plays a central role in accommodating changes, automating the decision-making process, and automating aspects of work and or the access to information needed to perform work, so we will put our focus on discussing strategic aspects about algorithmic trading through functional flexibility.

The main contribution is the adaption of TAFIM to a novel architecture framework for algorithmic trading information systems with three views specified with respect to systematic scalability, functional flexibility, and informative generality.

This paper has three sections. Section 2 presents a novel architecture framework and thoroughly discusses three views for an algorithmic trading information system: operational view in support of systematic scalability, strategic view developed to accommodate functional flexibility, and managerial view with focus on informative generality. Section 3 discusses a case study of algorithmic trading system from manual operation to algorithmic automation. And section 4 draws a conclusion of how the NATIS would work as well as future work.

2. NOVEL ARCHITECTURE OVERVIEW

While TAFIM represents a good start, we will have to help it "streamline" to be adapted to a novel architecture model for algorithmic trading with emphasis on either adjustable strategic aspects or functional flexibility. Three views for NATIS are developed with specific considerations in the algorithmic trading application area:

Operational view is used to describe the tasks and activities, operational elements, and information exchanges required to conduct operations. Furthermore, operations and their relationships may be influenced by new technologies such as collaboration technology, where process improvements are in practice before policy can reflect the new procedures (Liang & Sambasivam, 2010; Liang, 2008). With the support of ECN, systematic scalability in an input-process-output paradigm represents the ability of adding new processing modules into the system with ease, since an algorithmic trading system usually does not act as a standalone application, but appears as a node on the basis of input-process-output paradigm.

Strategic view describes the unique parts of systematic behavior, its activities, and how those activities contribute to success. It also creates options or alternative solution against the mission by re-organizing particular functions composed from strategic elements (Liang & Sambasivam, 2009). In other words, the cognitive process that reflects human strategies and intelligence is applied to stock trading with or without human intervention. Central to the strategic view is the ability to accommodate strategy adjustment, and operational options that automated trading can be done in alternative ways.

Managerial view defines how to organize various entities and attributes into a bounded set or system, in order for the outcomes can be controlled. In other words, we can manage, manipulate, and measure information to achieve control within the limits of our system (Liang & Sambasivam, 2009; Liang, 2003). Since all information communication dominates input / output (to or from the system), **general information management** plays an irreplaceable role in flexibly constructing algorithmic trading (information) systems.

Figure 5 illustrates that NATIS places the algorithmic trading system under a networking environment as both input node into the network and output node from the network. Strategic view in the trading environment plays the central part in accommodating, adjusting, and stimulating all activities to work in a highly coordinated way. Obviously, the algorithmic trading system acts as a componential system, under a system of systems environment, and is internetworked with other automated trading platforms. Later on we will see that ECN supports interconnection between such kinds of componential systems though API provided by vendors of trading platforms, such as Lightspeed (Automated Trading), Sterling (Trading Platforms) etc. Conceptually, functional flexibility is derived through strategic view, systematic scalability through operational view, and informative generality through managerial view, which will be discussed thoroughly in the next section.

Operational View: Systematic Scalability

Operational View for the NATIS describes the tasks and activities, operational elements, and information exchanges required to conduct operations. All the products and services are delivered through information communication with or without human intervention (manually or fully automated). A pure Operational View is material independent. However, operations and their relationships may be influenced by new technologies such as collaboration technology, where process improvements are in practice before policy can reflect the new procedures. With or without human intervention (manually or fully automated). **Operational activities** embody <u>systematic scalability</u> in an input-process-output paradigm, which means the NATIS usually does not acts as a standalone application, but appears as inputs and outputs that bring about mission-specific functionality.

Figure 6 illustrates the NATIS's Operational View that emphasizes systematic scalability. Differing from TAFIM, with the support of ECN, operational view in NATIS stresses Information Interchange, Human Computer Interaction, and Networking Interoperation between / among componential systems.

Systematic Scalability is the ability of an application to continue to function well when it (or its context) has changed in size or volume in order to meet the user's needs. Typically, the rescaling is to a larger size or volume. The rescaling can be of the product itself (for example, a line of computer systems of different sizes in terms of storage, RAM, and so forth) or in the scalable object's movement to a new context (for example, a new operating system). In our NATIS model, the central to the system scalability is embodied by I^3 capabilities: Networking Interoperation, Information Interchange, and Human Computer Interaction.

- <u>Networking Interoperation</u> or interoperability refers to both capability to interchange information between diverse components, and the ability for joint task execution over-the-network (Liang, 2008; Young et.al, 2001).
- <u>Information Interchange</u> or the exchange of information among applications shall be based on the logical data models developed as the result of identifying information requirements through activity or process models. The standard data elements shall be exchanged using the data management and data interchange services of application platforms. The intent is to exchange information directly between information systems without the constraint of formatted messages, subject to security classification considerations (Data Exchange).
- <u>Human Computer Interaction</u> focuses on interaction and specifically on interaction between one or more humans and one or more computational machines (HCI).

Significantly, NATIS supports algorithmic trading business in a scalable approach. In electronic financial markets, **algorithmic trading** is the use of computer programs for entering trading orders with the computer algorithm deciding on aspects of the order such as the timing, price, or quantity of the order, or in many cases initiating the order without human intervention. An **electronic communication network** (**ECN**) is the term used in financial circles for a type of computer system that facilitates trading of financial products outside of stock exchanges. That is to say, ECN is an electronic system that attempts to eliminate the role of a third party in the execution of orders entered by an exchange market maker or an over-the-counter market maker, and permits such orders to be entirely or partly executed (ECN).

Strategic View: Functional Flexibility
Strategic View for the NATIS describes the unique parts of systematic behavior, all activities, and how those activities contribute to the success. Strategic activities accommodate functional flexibility that acts like the brain to the algorithmic trading systems to create options or alternative solutions against the mission by re-organizing particular functions composed from strategic elements (Liang & Sambasivam, 2009). Mission-specific functional requirements in trading business, in terms of trading strategy, change from time to time, which is why we stress the flexibility that makes trading strategies adjustable through strategic elements in order to form particular functions.

Figure 2 illustrates the NATIS' Strategic View that emphasizes functional flexibility with the mission in "mind" that can split up into re-compostable objectives and measurable goals. Acting as the brain to the algorithmic trading business, strategic view in NATIS stresses accommodation to trading business (reflecting specific mission), automation of cognitive process (adjustable objectives and decision-making), and adjustment against strategy changes (embodied as measurable goals). With respect to Knowledgebase, it actually comes from Managerial View through data analysis, data mining, and data manipulation.

Figure 2. NATIS Functional Flexibility from Strategic View via Knowledgebase

Functional Flexibility is the ability of computer-based information systems to change easily in response to different strategies and system requirements. Generally, stock trading is like playing a chess game, a strategy is proved to be effective in a certain circumstance, but won't be working under another situation. In other words, functional flexibility allows adjustable objectives to be reflected by particular functions and enables measurable goals to be computerized to fulfill the mission (business purpose) through alternative solutions by creating different options. In our NATIS model, the central objective of the functional flexibility is embodied by A^3 capabilities: Accommodation to trading purpose, Automation of cognitive process, and Adjustment against strategy changes.

- Accommodation to business purpose refers to mission's fulfillment in alternative approach. In the trading process, high probability of win is the priority, but we may have different approach toward the direction.

- Automation of cognitive process or decision-making of application shall be based on the capability of reorganization of particular functions that certain objectives can be reached. Furthermore, the re-organized objectives become the key to the fulfillment of the mission (business purpose).

- Adjustment against strategic rules or elements focuses on quantitative strategic and / or knowledgeable elements (or rules) that the particular functions can be adjusted. In a programmable sense, this works like parameterization of functions.

Obviously, the mission-specific application's purpose is fulfilled through objectives with measurable goals. NATIS supports algorithmic trading by means of flexible-adjustment of the strategies and functionality. In reality, successful trading strategies work effectively in most cases, but if all the traders use the same strategy, the result would be negative for everyone. Therefore, there must exist a way for the trading expert to adjust the strategies when necessary. Although all the trading activities have the same mission or purpose of producing profit, objectives and goals need to be adjustable so that an alternative approaches can be used to fulfill the mission (Stock trading Strategy, Trading Markets, and Trending)

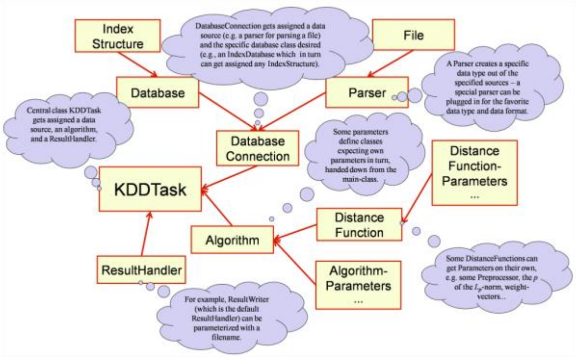

Figure 3. NATIS Informative Generality from Managerial View via Database

Managerial View: Informative Generality

Managerial View for the NATIS defines how to organize various entities and attributes into a bounded set or system, so that the outcomes can be controlled. In other words, from the viewpoint of management, an algorithmic trading information system is seen as an organization for control. Under this organization with many entities and attributes well managed, we can manage, manipulate, and measure information to achieve control within the limits of our system (Liang & Sambasivam, 2009). Managerial activities concern Informative generality which means all algorithms used for management, manipulation, and measurement are generalized that they can be instantiated when needed for specific types of data, information, or knowledge provided as parameters.

Figure 3 illustrates the NATIS' Managerial View that emphasizes informative generality via parameterization that database / information details can be hidden from the outside.

An important measure of the success of an IS and architecture is its ability to adapt to changing circumstances through information hiding and interchange. Generic programming is a style of computer programming in which algorithms are written in terms of to-be-specified-later types that are then instantiated when needed for specific types provided as parameters. This approach, pioneered by Ada in 1983, permits writing common functions or types that differ only in the set of types on which they operate when used, thus reducing duplication. Software entities created using generic programming are known as generics in Ada, Eiffel, Java, C#, and Visual Basic .NET; parametric polymorphism in ML and Haskell (the Haskell community also uses the term "generic" for a related but somewhat different concept); templates in C++; and parameterized types in the influential 1994 book Design Patterns. The authors of Design Patterns note that this technique, especially when combined with delegation, is very powerful but that "Dynamic, highly parameterized software is harder to understand than more static software." (Gang of Four 1995:21).

Informative Generality refers to features of certain statically typed programming languages that allow some code to effectively refine the static type system. For instance in C++, a template is a routine in which some parameters are qualified by a type variable. Since code generation in C++ depends on concrete types, the template is specialized for each combination of argument types that occur at some instantiation. Generic programming is commonly used to implement containers such as lists and hash tables and functions such as a particular sorting algorithm for objects specified in terms more general than a concrete type. In our NATIS model, the central to the informative generality is embodied by M^3 capabilities: management, manipulability, and measurement of information and data stored as trading knowledge, strategic intelligence in database.

- Information Management is the ability to collect and manage information from one or more sources and the distribution of that information to one or more audiences. This does a great favor in support of information interchange through operational view.

- Data Manipulation is the ability to process data to form useful information assists in the decision making process. Data manipulation language defines the interface between a data base and an applications program, which is embedded in the language of the applications program and provides the programmer with procedures for accessing data in the data base.

- Knowledge Measurement organizes knowledge representation to the quantitative extent that the application can measure, statistically analyze information for decision making, which does a great favor in support of strategic accommodation to functional flexibility.

The "Golden Rule of Data Manipulation" is a simple but important rule that should always be followed when designing a database, writing database code, or writing *any* application code at all for that matter:

"It is always easier and more flexible to combine data elements rather than to break them apart"

Informative generality establishes the firm foundation in support algorithmic trading via Electronic Communication Networks. Without Informative Generality, it would be really hard to fulfill networking interoperation, information interchange, and human computer interaction.

3. CASE STUDY: STAR TRADING SYSTEMS AT YOOTECH

Before discussing the case study, we need to introduce a bit trading principle. The trading chart represents price and trends for stock trading. When the curve goes down, it indicates a good chance to sell your stock; when the curve goes up, it indicates a chance to buy. So an Algorithmic Trading Information System is supposed to process the data from market (live data: NYSE or Nasdaq), predict the trends and act with order positions (submit BUY/SELL order via ECN), shown as Figure 4.

Figure 4 illustrates how a trading action leads earning money or losing money. When the angle leads to going down, it is a good time to sell (shorting) at the higher price, and when the angle turns ups, it is a good time to buy at the lower price.

Figure 4. Buy or Sell (short) on Trading Stock

In electronic financial markets, **algorithmic trading** is the use of computer programs for entering trading orders with the computer algorithm deciding on aspects of the order such as the timing, price, or quantity of the order, or in many cases initiating the order without human intervention. Algorithmic trading via ECN, regarded as typical computer information systems, involves information technology, and people's activities using that technology, to support operations, management, and decision-making.

Figure 7 gives a typical example that combines both manual and algorithmic trading application. The automatic (algorithmic) trading is a closed loop where the algorithmic process dominates trading process. eSignalStar as input to this closed loop: it receives market data on a real time basis (e.g., NYSE), and analyses historic patterns from databases, and then sends a e-signals (triggers) to the ECN-TradingStar that automatically executes trading orders to trading platforms. Manual trading process is an open loop where traders are in control, but the whole process similar to the automatic one: eSignalStar receives market data, and analyses historic patterns from databases, and then sends e-signals to the screen for the trader, then the trader make his own decision accordingly and put trading orders to database (timely tagged order), so that ECN-TradingStar executes the submission according to the tagged time.

Two important components in such a system: ECN-TradingStar, and eSignalStar. The former automatically executes submission of trading orders to an exchange (trading platform) through ECN, such as Lightspeed (Automated Trading), Sterling that provide trading API to algorithmic trading development company. The latter dynamically generates signals to stimulate traders (manually putting orders through spreadsheet) or directly drive ECN-TradingStar to submit orders in a fully automated way.

Apparently, trading process referring to *when* to submit the order, at *what price*, and in which way to act (*buy or sell*) reflects highly intelligent analysis and process according to historic data (Database recording strategic knowledge, experiential patterns, on the basis of timeliness and consistency).

From the viewpoint of NATIS, all the components including NYSE (Stock Exchange Center), LightSpeed, ECN-TradingExec, and eSignalStar are connected via ECN, which reflects networking interoperation in Operational View, and within the interior rectangle, eSignalStar represents strategic view, while ECN-TradingExec operational view, and Database managerial view.

eSignalStar is a reasoning and analytical system that works out signal to trigger trading through strategic elements, particular operations, and quantitative message to be reported to the trader (manually) or ECN-TradingStar (fully automated). ECN-TradingStar is a transaction processing system based on database and eSignleStar's trigger. The only difference between manual submission of orders and fully automated submission is that the former does with human intervention and the latter does without human intervention. However an expert-level professional may adjust the strategies of trading that eSignalStar will be affected to meet new requirements.

4. CONCLUSION

Computer Information Systems (CIS) are broadly applied to many areas, but the complexity of constructing CIS challenges us with demanding flexible infrastructure framework to accommodate various and heterogeneous components be integrated into an internetworking system of systems (SoS) as a whole. TAFIM, recommended as a valuable reference model for enterprise architecture development, defines a target common conceptual framework as an information system infrastructure, but is NOT a specific system design. NATIS, derived from TAFIM, mainly contributes to flexibly constructing Information Systems -- Algorithmic Trading Systems in particular, with emphasis on systematic scalability, functional flexibility, and informative generality through three views.

Sophisticated technologies such as middleware, software architecture, and database manipulation language (e.g., SQL server) have been well developed in support of **operational view** that stresses networking interoperation, information interchange, and human-computer interaction), and **managerial view** that stresses the management, manipulation, and measurement of data, information and knowledge applied to trading business. Difficulties in developing **strategic view** still challenge the developers. At Yootech Associates, we have successfully developed series of Star Technologies, e.g., ECN-TradingStar, and eSignalStar, etc., but have been challenged for a long time by how and when to adjust trading strategies. We expect a great breakthrough on strategic view with NATIS in the near future.

Algorithmic Trading is challenging, but we enjoy being challenged because we know the material extensively and have the effort to move forward. As a result with NATIS, flexibly constructing automated stock trading is made not only feasible via Electronic Communication Networks, but also possible when trading strategies need to be altered to take advantage of various exploitable situations.

5. ACKNOWLEDGEMENT

We are very appreciative for Yootech Associates and Azusa Pacific University (APU) that give us a chance to deepen our research on advanced Information Technologies and apply CIS to Algorithmic Trading via ECN. The research and practice result not only benefits us as IT professionals, but also enriches our teaching on Computer Science and Computer Information System -- richness of teaching comes from systematic scalability, and functional flexibility – the former allows students work on the project in group with ease of integration of parts into a system, while the latter gives our students more freedom to implement functionalities under certain requirements.
More gratefully, NATIS also provides us a wonderful platform that makes all the running data lively meaningful, where queues (data structure FIFO) have their own life – the data should be processed to make money (trading), and delay leads to loss of money. Acknowledgement also goes to the cooperation between Yootech and CS department in APU.

6. REFERENCES

Altucher, J. (2004). Trade like a Hedge Fund – 20 Successful Uncorrelated Strategies & Techniques to Winning Profits, John Wiley & Sons, Inc.

De Lemos, R. (2004). Quantifiable Software Architecture of Dependable Systems of Systems, Chapter in book: Architecture Dependable Systems II, ed. Springer Verlag.

Liang, S. (2003a). Quantifiably Architecting Dependable Systems of Embedded Systems, ACM SIGSoft, Software Engineering Notes, Vol 28 (6), November, 2003.

Liang, S. (2003b) Composition Modeling: To wards a Prototype-driven Product Transition¸ ASTED Intl. Conf. on Software Engineering and Applications, Marina Del Rey, 2003.

Liang, S., & Sambasivam, Samuel. (2010). PADT: SSAD-Streamlined and Component-Based Development -- Perspective, Activity, and Documentation Transitioning Approach accepted by ICEME 2010, April 6-10, Orlando, FL.

Liang, S. (2008) re-ADA: reliable Ada-based Descriptive Architecture for C4ISR via a quantitative interoperating Model, Proc. of SIGAda08 Annual International Conference, Portland, OR, 2008.

Liang, S., & Sambasivam, Samuel. (2009). "Automatic Prototype Generating" Restated with re-ADA --- Perspective-bridged Architecture for Document-Driven Systems, ACM SIGAda AdaLetters, 2009.

Liang, S. (2003) Software Documentation-Driven Manufacturing -- Viaduct between Software Engineering and Virtual Engineering, Proc. of COMPSAC 2003, Nov. 3-6, Dallas, TX.

TAFIM: DoD Joint Technical Architecture (JTA Version 6.0, 2003), http://www.acq.osd.mil/osjtf/pdf/jta-vol-I.pdf

Young, P., Berzins, V., & Ge J., Luqi. (2001) Use of OO Model for Interoperability in Wrapper-Based Translator for Resolving Representational Differences between Heterogeneous Systems, Monterey Workshop 2001 – Engineering Automation for Software Intensive System Integration.

Appendix: Charts and Diagrams

Figure 5. NATIS with three views

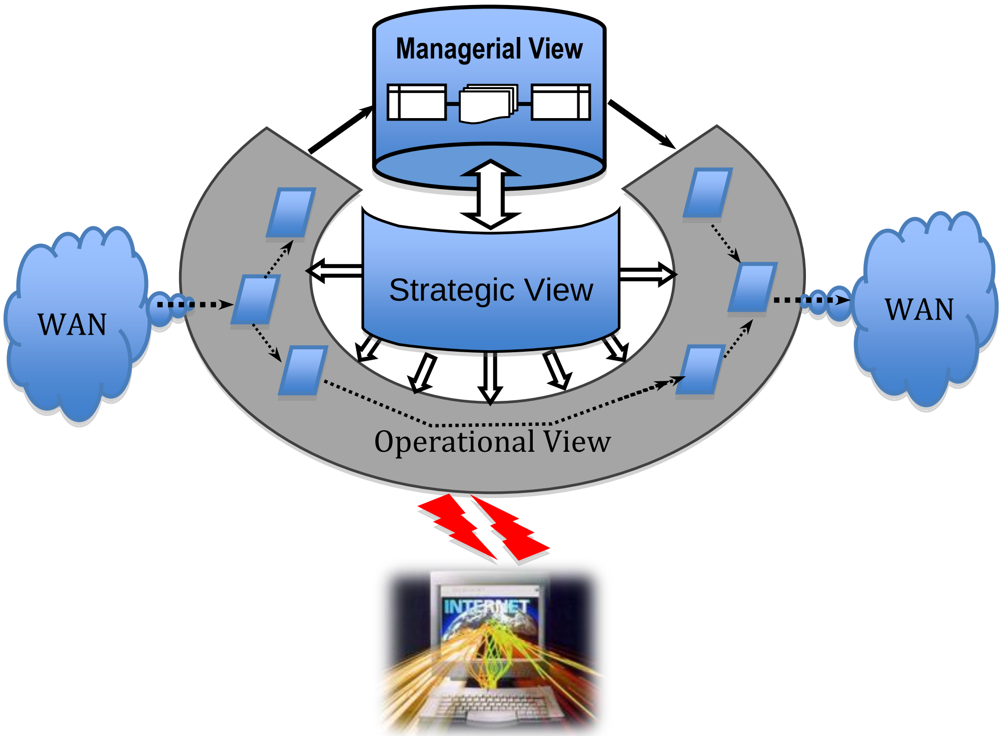

Figure 6. NATIS Systematic Scalability from Operational View via ECN

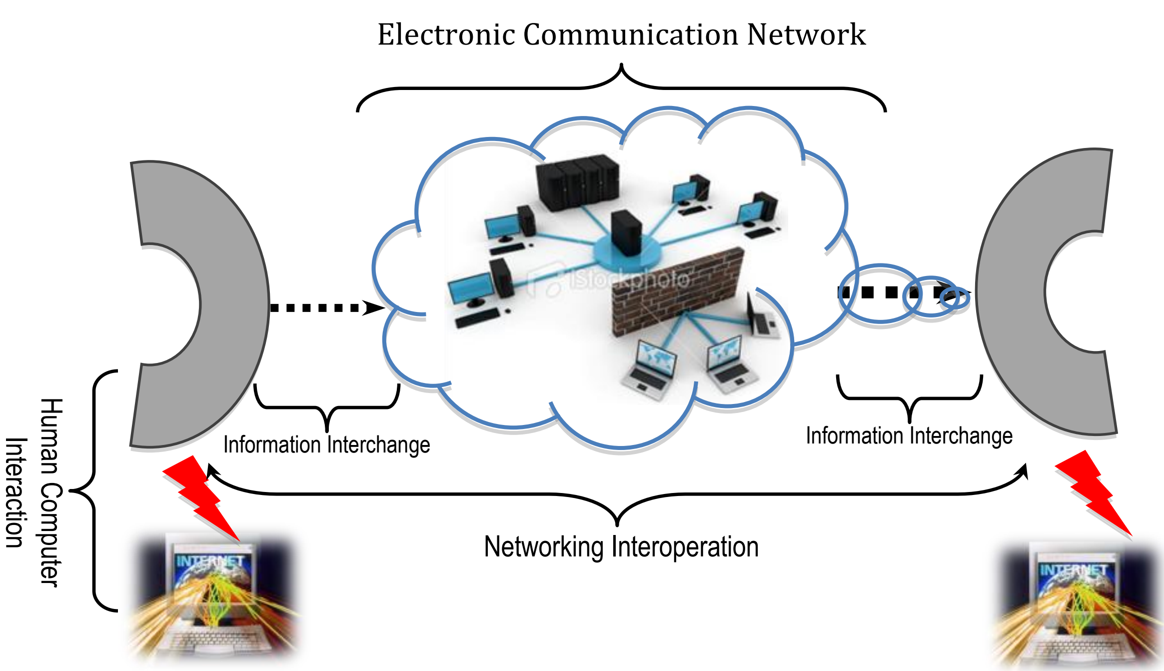

Figure 7. StarTrading System at Yootech Associates