An NFC-Enabled Anti-Counterfeiting System for Wine Industry

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Abstract

Wine counterfeiting is not a new problem, however, the situation in China has been going worse even after Hong Kong manifested itself as a wine trading and distribution center with abolishing all taxes on wine in 2008. The most basic method, printing a fake label with a subtly misspelled brand name or a slightly different logo in hopes of fooling wine consumers, has been common to other luxury-goods markets prone to counterfeiting. More ambitious counterfeiters might remove an authentic label and place it on a bottle with a similar shape, usually from the same vineyard, which contains a cheaper wine. Savvy buyers could identify if the cork does not match the label, but how many “normal” consumers like us could manage to identify the fake with only eye scanning?

NFC facilitates processing of wine products information, making it a promising technology for anti-counterfeiting. The proposed system is aimed at relatively high-end consumer products like wine, and it helps protect genuine wine by maintaining the product pedigree such as the transaction records and the supply chain integrity. As such, consumers can safeguard their stake by authenticating a specific wine with their NFC-enabled smartphones before making payment at retail points.

NFC has emerged as a potential tool to combat wine and spirit counterfeiting, undermining international wine trading market and even the global economy hugely. Recently, a number of anti-counterfeiting approaches have been proposed and adopted utilizing different authentication technologies for such purpose. The project presents an NFC-enabled anti-counterfeiting system, and addresses possible implementation issues, such as tag selection, tag programming and encryption, setup of back-end database servers and the design of NFC mobile application.

The integrated system is consisted of different component hardware and software, and so the best combination of settings, parameters and deployments should thus be identified. The critical design of the whole NAS is vital not only the key to prevent the supply chain from wine counterfeiting problems accordingly, but also the strong foundation for those later built supply chain systems such as the NFC purchasing system, which is built top of the NAS providing anti-counterfeiting functions using merely a smartphone. For the Video Demo of the NAS, please view it at http://youtu.be/qOWPibxESL4.
Chapter 1 – Project Backgrounds

1.1 What is NFC-enabled Anti-Counterfeiting System (NAS)?

The NFC-enabled Anti-Counterfeiting System (NAS) is an integrated and “open” system tailor-made for winemakers, the supply chain partners and wine consumers, aiming at operating two mobile applications to direct the NFC-enabled smartphone using its NFC technology to connect with the back-end database owned solely by the winemaker through scanning those NFC tags on those wine bottle openings, have already been developed and setup for the purpose of prompting consumers to authenticate bottles of wine at the retailer points.

The whole NAS is consisted of FIVE main components, which are 1) the back-end system for wine data management performed by the winemakers, 2) an mobile application, ScanWINE, for tag-reading purpose of wine products at retailer points for wine consumers or partners before accepting a wine, 3) another mobile application, TagWINE, performing tag-writing purpose for wine at wine bottling stage by the winemakers, 4) the NFC tags attached on the bottleneck for those purposes and actions, and 5) the NFC-enabled smartphones or tablets.

NAS allows partners or consumers utilizing an Authentic App with their NFC-enabled smartphones to identify wine’s authenticity and integrity anytime and anywhere, providing the authentic wines with sound provenance using the cheap and available technology – NFC, at retailing points. While the winemakers could utilize a Synthetic App with their NFC-enabled handheld devices (or simply their NFC-enabled smartphones) to provide extra security with NFC technology in addition to those existent labeling technologies already being adopted onto the wine bottle for delivering anti-counterfeiting values.

NAS has been addressing security of wine from its birth with NFC labels pasted, since it is an open-and-break, recycling-prevented, and clone-prevented system. It offers convenience and simplicity to those wine consumers, partners and winemakers without requiring special tools or sound wine education background to be actually exploited. The NAS is also suitable for all kinds of wine bottle, with specific design of NFC tags working on metallic packaging materials, like foil package, providing multi-lingual verification platforms and promoting connection between original winemakers, partners and consumers.

The NAS is designed to be like the frangible label was broken once the wine was uncorked to prevent recycling the bottle. NAS may be the more secured and available solution for different industry players to protect their own interests. The NFC hardware setup costs are low compared with the value of wine products, and hence the expenses of system implementation will be justifiable, as the high prices of wine provides enough incentives for building NAS.
Chapter 2 – Rampant Counterfeit Problems in International Wine Trade

2.1 The Attraction of Wine to Counterfeiters

A variety of news reports and events have already created a situation where wine products have been very attractive for being counterfeited. However, you may ask why wine would be an attractive target, and some have suggested that it is probably because they are valued and priced. Some reviews believed that the recent emergence of those spectacular vintages, like 2000 and 2005 Bordeaux, has already fueled the situation of wine counterfeiting as the market of those extravagant and rare wines and even the wine bottles, has become superheated, making it a hotbed for counterfeiters. As such, the more valued and rare the wine is, the more it could be supposed that winemakers maybe targeted for wine counterfeiting [1].

There are various reasons why wine itself, and its some attributes, making it to be susceptible to be the main target of frauds and counterfeits. For instance, the prices and market values of fine wine have been soaring in recent years owing to the limited supply, diminishing supply of those older vintages and the increasing wealth creating more potential buyers in those developing wine markets and countries such as China, India, etc. [2] The above reasons have already created a vast opportunities for those counterfeiting activities to make money and pose a negative impact on the wine industry and international wine trade. It is not surprising to say that many wine consumers are not really familiar with the knowledge and technique of wine appreciation and recognition. It turns out that there have been other reasons why the wine is attractive for counterfeit, like the difficulty in proving provenance of those vintage wine bottles and the variability of how those old vintages taste.

The wine counterfeiting has been getting more aggressive and sophisticated, particularly due to the rising bottle prices rise contributed by the huge demand in the Chinese wine market. With popular empty bottles gathered and even available for sales in China with attractive price, rebottled wine problem with cheap wine and chemicals refilled is rampant in China. For instance, the bottles have been seen copying with the original label, artwork and trademarked name, with slight change on the name and logo of the originals. It has been then different enough not to be a counterfeit but still fool wine consumers. The bottles have always been regarded as originals, since some new or unsuspecting wine consumers and some supply chain partners are not familiar with the real label because of their lack of wine knowledge and, maybe, the inability to read French or English making the situation even worse. Some counterfeiters in China also purchase empty wine bottles with cheaper wine or unknown liquor simply refilled using a syringe, re-cork the bottles, and replace the capsule packaging materials, and sell the bottles as new to market. These types of wine counterfeiting techniques in China are much easier to pass off as the original than bottles produced by cloning the original labels.
2.2 Evidence that Wine Counterfeit Market Grows

The recent increased publicity on the counterfeit wine has given a large body of evidence that counterfeiting exists on a variety of different levels, and even in a growth throughout the international wine market. Specifically, there is growing evidence of fine wine counterfeit market and even the whole counterfeit industry.

Indeed, the US government also estimated the global wine counterfeit industry, with quite different definition on wine counterfeiting, at $5 billion (USD) with a growth rate of 1,700% over the past 10 years in 2008 as well. Similarly, the IACC, in 2012, reported that wine counterfeiting is a $6 billion (USD) a year problem, and it was in fact that the problem has grown over 10,000% in the past two decades, in part fueled by consumer demand and the limited effectiveness of those labeling technologies applied to the wine industry. The following chart demonstrates the estimates on the size of the wine counterfeit market done by the two organizations, and the previous estimates, from 1972, based on the trend as specified by both the organizations.

Concerning the wine counterfeiting market, there has been a pile of reported cases of counterfeit wine over recent years all around the world. Some of the more famous cases including 1990 Penfolds Grange, 1994 and 1995 Sassicaia worth over £1 million and fake Rioja estimated at one million bottles under which a famous wine collector, named William Koch, issued lawsuits over the counterfeited wine claiming his magnums of 1921 Chateau Pétrus, valued for about $ 4 million (USD), was filled with cheap California Cabernet [3]. Some even happened that the vintage that was never produced by the original wine producers. Burgundy winemaker Laurent Ponsot discovered that 106 out of 107 bottles of his wine at auction were faked including a sale of Clos Saint Denis 1945 and other old vintages they didn't even begin producing this particular appellation until 1982 [4].
2.3 Current Anti-counterfeiting Techniques Adopted in the Wine Market

As the wine counterfeit has become a more public issue, a bundle of anti-counterfeiting companies have developed and marketed their innovations and technologies towards the wine industry. This section is to provide a summary of the techniques utilized to combat wine counterfeit.

There are more wine trade techniques for wine authentication. For example, examining the vintage corks has also been one of the core anti-counterfeiting techniques. Due to the fact that corks have appeared to be really tough to be copied, compared with the any other aspects of the wine products, which could easily be copied. It appears even more secured that corks have been branded, and the original branding ink might be paler when the time goes by, but often the year of origin would be still clearly visible for viewing. Actually, it will be possible to detect the anomalies on the cork through the glass with a bottle sealed, only for those wine professionals. Provided that this is one of the primary ways to verify the wine, the wine has to be uncorked by non-professional wine consumers so that the wine could be authenticated [1].

It seems that authenticate a wine through examining the cork is not common and has transferred low effectiveness to the industry as wine consumers will less be possible to authenticate a wine using this technique. Is there any technique could be adopted easily by wine consumers and even without the need of uncorking a wine, like at retail points before making payment? Yes, the advent of labeling technologies applied on wine industry could help. So as to relieve the expanding wine counterfeit market, the UPC Barcode first applied to the industry in 1974, followed by the QR codes and RFID in 1994 and 2004 respectively as shown on the line chart.
Nonetheless, there have been rapid changes in the technology applied on counterfeit prevention and even for the anti-counterfeiting purposes. However, counterfeiters have likely been only a step behind the introduction, so the longevity and the trustworthiness of any existing labeling technology have been questioned. Though there is a series of labeling technologies available for combating the serious wine anti-counterfeiting, doubtful authenticity of certain wines with labels counterfeited, such as barcodes, QR codes and even RFID tags. While the wine industry players are becoming increasingly aware of the potential negative ramifications of counterfeit parts with altered serial numbers, barcodes and QR codes sourced and distributed in the supplier networks or along the supply chain. In fact, wine industry players have regarded RFID tags as labeling solutions that can ultimately protect their products and their brands; however, doubts and threats such as self-replicating RFID virus, cloning of RFID tags and replay attacks could be addressed during the RFID application to the wine industry [6]. Although there are still new technologies, like the Applied DNA Sciences botanical test, Jean-Charles Cazes of Chateau Lynch-Bages also stated that: “For us right now there is no technology which we are sure would be viable on the market in 20 or 40 years.” [5]

The incentives of building the one-of-a-kind NAS were then supported by the above opinions covered and visualized in response to the in emergent needs from the wine industry, especially in China, leading an open, rapid and affordable anti-counterfeiting system adopted with newer labeling technology – NFC, in which the technology has never been adopted in the industry for such purpose, should therefore be developed in this project.
Chapter 3 – Selection, Deployment and Preparation of Project Tools

So as to construct the whole systems, there will be a bunch of software and hardware to make it happen; for instance, software is needed for constructing both the database servers and those authenticating apps, and hardware such as NFC tags and NFC-enabled smartphone should be narrowed down so that those database and apps could be integrated into the hardware and make the whole system running in reality.

3.1 Selection of NFC-enabled Device

In today’s market, there is only Android platform could be compatible with NFC technology. It implies that all the NFC-enabled smartphone are actually running Android operating system, instead of Apple’s OSX, so what we need so as to simulating the whole NAS, is to source an NFC-enabled smartphone such that apps utilizing NFC technology of the hardware, could therefore be built and run on this NFC-enabled smartphone.

There are in fact 114 NFC-enabled smartphone in the market. But how should we determine which smartphone is the most suitable one? What will be the selection criteria of the desired smartphone of the NAS? There will be major FIVE points to fulfill. First, the phone should be implanted with the updated model of NFC chips and controllers. Second, the NFC-enabled chip should be found compatible with as most NFC tag in the market as possible. Third, the smartphone must be released after Fall 2011, which was the released season of the one-of-the-kind universal NFC tag – NTAG203. Fourth, the selected NFC-enabled smartphone must be compatible with the universal NFC tag – NTAG 203 and other Type 2 NFC tags. Fifth, the smartphone must be equipped with basic technical requirement, like implanting with Quad-core processor, running at least on the Android 4.3 (Jelly Bean), built with Wi-Fi and Bluetooth, etc.

We have then narrowed down the latest Samsung release – the Samsung Galaxy Note 3 (Model Number SM-N9005) as the main NFC-enabled device and the desired smartphone that we built NFC-related on, as the Note 3 does meet all the criteria needed for the NAS. Samsung Galaxy Note 3 is the latest model of the Galaxy Note Series, it is NFC-enabled, and its NFC controller is also compatible with the NXP NTAG203, fulfilling all the remaining requirements as well.

The NFC controller chip of the desired NFC-enabled smartphone will be Broadcom BCM20793S. For the compatibility with NFC tags, the NFC controller chips support Type 2 NFC Tags. There will be also some NFC-enabled smartphone fulfilling the criteria of NAS, but not the most suitable as Samsung Galaxy Note 3 does. There will be a full list of all the NFC-enabled smartphones or device in the market on the Appendix 1.
3.2 Selection of the NFC Tags

An NFC Tag is an unpowered passive target consisting of an NFC PCB chip and an antenna in a substrate. Tags have a relatively low RF (radio frequency equals 13.56 MHz), too weak for intense interaction. When exposed to an “initiator” (a reader, a writer or a smartphone) with a more powerful RF field, the tag’s RF field is strengthened, and then reading or writing can be done. Most NFC tags contain standardized NDEF messages, which are parsed and shown on-screen, formatted to easy readable content. NDEF is strictly a message format, a common data format for NFC Forum-compliant tags and devices, and for tag reading/writing.

Likely, there is a group of FIVE selection criteria set so as to narrow down the most suitable NFC tags for the whole NAS, which are, 1) the compatibility with the NFC controller chip of the selected NFC-enabled smartphone for the NAS, the 2) material onto which the tag is applied, 3) the tag size, 4) the tag memory capacity, and the 5) write endurance of the NFC tags. There are also some minor criteria, which are price, and the ease of purchasing.

Regarding the compatibility with the NFC-enabled smartphone selected for the NAS, which was the Samsung Galaxy Note 3. The NFC controller chip of that smartphone is aforementioned Broadcom BCM20793S. (For the one we brought outside US areas) Based on the NFC Forum Type Tag Platform, NFC Standards, Products existed and its specification. (Please refer to Appendix 2), it was realized that those NFC tags with the NFC Forum Type Tag Platform – Type 2 Tags would be suitable and compatible with that NFC controller chip implanted in the Samsung Galaxy Note 3. In short, our targeted NFC tags will ONLY be those under the group of “Type 2 Tag”.

Based on the first criteria, we already came up with the fact that only Type 2 Tag will be chosen for further screening, which would be Mifare Ultralight (UL), NTAG203, Mifare Ultralight C, Kovlo 2Kb RFID, etc.
For the tag physical size, it would be better that if those tags could be in shape of circle and around 25-35 mm of diameter with at most 0.5 mm in thickness for wine with 0.75 liter. While the write tag memory capacity should be better with 144 Bytes (For Type 2 Tag, there is only 48-byte or 144-byte for choices), and the write endurance should be at least 10000 times. Through integrating with all the criteria in the above, there are FOUR NFC tags selected and bought, which are all produced by NXP Semiconductors, and bought from Shanghai and Shenzhen in which three are Type 2 in nature and the one is Type 7 in nature. For those three Type-2 NFC tag, two of them are actually NFC Ferrite Tag for which the NFC tag making the whole NAS enable to work and operate under the metallic environment such as the foil packaging around most of the bottlenecks, which were introduced in the improvement stage so as to further improve the NAS after the usability research.

NTAG203 is the most universal NFC tag in the world, under which it has been compatible with and supported by most of the models of NFC-enabled smartphones or devices, which will in all likelihood be suitable to the NAS we developed. For Mifare Ultralight (UL) C, it is developed and designed for limited use applications such as authentication and NFC Forum Tag Type 2 applications, which is a more secured version of Mifare Ultralight (UL) born with 3DES encryption. An intelligent anticollision function according to ISO/IEC 14443 allows operating more than one card in the field simultaneously. The anticollision algorithm selects each card individually and ensures that the execution of a transaction with a selected card is performed correctly without data corruption resulting from other cards in the field. As such, there will not be 2 NFC tags being read at the same time.

For Mifare Class 1K, The MF11CS50 is designed for simple integration and user convenience. Which could allow complete ticketing transactions to be handled in less than 100 ms. The most suitable one with the NAS will further be determined once the NAS would be ready later on for a series of tests for different situation, user cases and categories of tags. This tag was bought for the purpose of control experiment to determine whether the NFC controller chip could be compatible with this Type-7 tag or not. All the details of the NFC tags and NFC-enabled smartphone will be included in the Appendix 3.
3.3 Introduction of NFC Ferrite Tag (Anti-Metal Tag)

After the first demonstration, those NFC tags bought before were proved not available for working around metallic environment. A set of NFC ferrite tags, which were 1) *NTAG 203 NFC Ferrite Tag* and 2) *Mifare Ultralight (UL) C NFC Ferrite Tag*, were then purchased so as to tackle the problem of metallic interference.

The NFC Ferrite Tag (Anti-metal tags) can work on metal surfaces because the anti-metal, Ferrite covering materials shields the NFC antennae from the metal surface. For example, when there is a metal object, like the foil packaging material surrounding the wine bottleneck, near the NFC tag’s antenna, the Ferrite sheet, which is like a thin magnetic sheet, will be required on the NFC tag to avoid communication failure caused by the metallic interference. It is believed that the NFC Ferrite Tag can change the magnetic flux path to avoid interference the NFC tag, high surface resistance and effectiveness in preventing resonance and suppressing coupling.
Chapter 4 – The Proposed NFC-Enabled Anti-Counterfeiting System

4.1 System Overview of NAS

So as to relieve the current rampant situation of wine counterfeit in emerging market and countries, this project proposes an anti-counterfeiting system aimed to provide an up-to-dated wine pedigree that supply chain partners and wine consumers can both share and receive while using the NAS for the purpose of wine authentication. The anti-counterfeiting mechanism was then designed and constructed based on a “hypothetical” winemaker, named **The Natural Wine Company**, and based on the auto-updating approach whenever there is a NFC scanning process being carried out by the wine supply chain partners with their NFC-enabled device for pedigree update of the wine, such as the record of wine acceptance by the next node throughout the supply chain of specific wine. The system also enables the wine consumers to authenticate the wine through their own NFC-enabled smartphone at retail points before making payment for it. The Video Demonstration of NAS will be available at [http://youtu.be/qOWPibxESL4](http://youtu.be/qOWPibxESL4).

NAS requires various partners along the supply chain to record and update the wine transactions applying the NFC technologies of the NAS. As such, supply chain integrity is maintained by forming a chain of custody from the wine transaction records stored in a central database owned only by the winemakers, under which only the winemakers will be allowed to modify the data store in the back-end database for a specific wine. All the supply chain partners are expected to verify the incoming wine and reject those with a suspicious wine for which no data is return during the NAS scanning process. The system primarily targets at high-end fine wine products. The NFC hardware costs are relatively low compared to the value of these wine products, and hence the system implementation cost will be justifiable. More importantly, the high values of these wine products provide enough incentives for wine consumer to verify them, using their own NFC-enabled smartphone, instead of the one provided by the retailer, before making payment.

As we aforementioned, The NAS is consisted of mainly three parts to make it possible, which are the 1) back-end database servers, 2) the NFC tags compatible with the NFC-enabled handset selected and 3) two applications running on the NFC-enabled smartphone. Wine consumers could simply tap to check an authentication certificate to confirm the originality of a luxury wine with full wine pedigree, wine details and even the wine pictures returned, and the winemaker could also simply tap to edit and add data of a specific wine while carrying out the bottling process in manufacturing.
4.2 The Design Methodology of NAS

The anti-counterfeiting system can be accessed through the Internet. It is divided into FOUR layers – the Application Controller Layer, the Wine Database Layer, the User Execution Layer and the Internet Protocol Communication Layer. The Wine Database Layer is comprised of the database itself and its database management system owned by the winemakers. The Application Controller Layer actually provides users and those NFC-enabled devices to access to those server logics, server controllers and the corresponding user interfaces, as well as sending request to the wine database. The Data Interchange Output Layer and Internet communication protocol provides communication standard for both Application Controller Layer and User Execution Layer to communicate with each other. While the User Execution Layer can be accessed through the Hyper Text Markup Language (HTML) or through the JavaScript Object Notation (JSON) using the Hyper Text Transfer Protocol (HTTP) for sending requests to the Application Controller Layer. Both the Wine Database Layer and the Application Controller layer are connected over a Local Area Network (LAN) own by the winemaker, while those Application Controllers interface with the components of the User Execution Layer through the Internet. The Wine Products Database, the LAN Wireless Router and the Application Controller Layer must be separated with firewalls in the middle to prevent from outside attacks.

Regarding the Wine Database Management Layer, the wine database is acting as a heart of the whole NAS and it supposed to be solely owned by the winemaker. It consists of tables that record the wine pedigree information, including the wine product details, the vintages, the transaction records, and the related project along with supply chain information regarding the specific wine. The wine database system updates, retrieves and sent out the required information from or to those tables involved according to the instructions given by the Application Controller Layer, thus integrating the supply chain data with transaction record systematically, logically and automatically to form the wine pedigree based on the request sent from the User Execution Layer. In short, this layer stores the wine records produced in the workstation of those winemakers.

The Application Controller Layer is where the operating logic and control of user interface of the NAS are stored and executed. The operating logic is mainly composed of C# and JavaScript syntaxes to perform the operations the five application controllers such as the 1) Project Record
Controller containing logics of those related wine records for specific project, 2) the Supply Chain Information Controller containing logic of operating that information of those supply chain partners, 3) the Wine Record Controller containing logic for managing those wine records such as responding for the request with accurate wine record and performing control of user interface for the wine management database, 4) the application controllers of the TagWINE (Winemakers) and 5) ScanWINE (Wine Consumers and Partners) in which they contain the operating logic of the wine record request and retrieval communication mechanism between the User Execution Layer and the Wine Database Layer. A set of JavaScript code set in the Applications and C++/C# code set in the “AppController” of the back-end Microsoft SQL database are used to access the data stored in the wine database in the Wine Database Layer and returned the required data back to the application running on the NFC-enabled device. In addition, the Visual Studio and Eclipse Toolkits will be needed if there are interactions between the Wine Database Layer with both the Microsoft SQL database of those supply chain partners and the TagWINE applications under the User Execution Layer.

While the Data Interchange Output Layer is where the HTML and JSON are utilized to publish the contents generated by the NAS, and these contents will then be output and transferred to the User Execution Layer for users to execute business and buying decisions. The users could make instructions or requests, such as agreeing the partnership, to the winemaker’s back-end database using the “Partners” version of web-based database with the desktop, laptop or smartphone through using HTML. The instructions, such as wine acceptance, updating the transaction record and requesting for specific wine record while at the retail points, can also be made by scanning an NFC tag attached on the wine bottle and transmitted back to the Wine Database Layer through the JSON. The JSON could ensure the machine-to-machine without human intervention to suit the fast-moving nature of the supply chain through using the NFC tag as the apps will send data output with this format to the Application Controller Layer, which is also the reason of employing NFC in the track-and-trace system in which the associated decisions will be made automatically by the machines (the apps and the controllers). The red line stands for the fact that the NFC-enabled smartphone could send requests to the Wine Database Layer through both the HTML and JSON as the smartphone itself can access mobile version of the web-based databases of those supply chain partners and perform those NFC-related functions with the app running on it respectively.

For the User Execution Layer, where an user loads an interface from the Application Controller Layer to operate a system and to make purchasing and business decisions, the Hyper-text Mark-up Language (HTML) pages are enhanced by Cascading Style Sheets (CSS) and JavaScript to improve the user-friendliness of the system. The user instructs the corresponding application controller to perform the business logic through the User Execution Layer. The results are transferred to and displayed on the user interfaces at the User Execution Layer. The red highlighted cluster means both the supply chain partners and wine consumers could utilize the mobile version of web-based databases running on desktop, laptop and smartphone, represented in blue line, to perform functions.
4.3 System Architecture of NAS

The below graph is a general operational structure of the NAS. For the web-based wine database owned solely by the wine producers, there are mainly two modules of information system, which are the 1) Producer Information System and the 2) Wine Seller Information System. The former is actually a system consisted of wine details, user feedbacks, wine reviews, etc. It only stores information only about the wine, under which the winemakers will key in information to update the system, and in return, the system could provide winemakers with information about the wine for further improvement on the product and the better practice in product management. While the latter is consisted of transaction records of specific wine products, the details of the supply chain partners, which could be distributors, wholesalers and resellers, of the winemaker, the details of project involving sales of a combination of wines between the winemakers and specific supply chain partners. Both modules will then be connected and integrated together through the Local Area Network (LAN) and form a Microsoft SQL database 2012, which is exactly the web-based wine database owned by the specific winemaker. The web-based database is actually connected with the web service which is a platform that the wine database communicate with the apps running on the NFC-enabled device, through those application controllers deployed both at the apps and the web service platform of the back-end database.

While at the users’ end, the wine consumers perform steps to authenticate a specific wine at retail points or when the wine is being accepted by the next nodes throughout the supply chain of the wine, through open ScanWINE, running on the NFC-enabled smartphone. A supply chain partners could also turn on the ScanWINE running on their NFC-enabled device, using NFC technology to scan the NFC tag attached on the wine bottleneck. In the mean time, the NFC tag acts a bridge to link the application and back-end database up based on the WID (Wine ID which is a basic element of tag value) stored in the tag. With WID, the specific wine record could be located and referred by the application, for which the communication, like the request sent from the application for the information of specific wine record based on the WID scanned and the wine record return from the back-end wine database, could be constructed with JSON format through HTTP with the application controllers under the web service platform, using Wi-Fi or GPRS provided by those ISP in the region.
When a specific wine was produced and being transferred hands by hands throughout the supply chain, the wine record like the transaction record of that wine will be automatically updated simultaneously once the tag affixed on the wine bottleneck was being scanned with an NFC-enabled devices owned by the supply chain partner in every mode throughout the supply chain. For instance, when the supply chain partners adopted the NAS and using the NFC-enabled smartphone to scan the NFC tag while they accepted the wine intelligence from the winemaker, the ScanWINE app running on the device will connect to the Authentication Controller of the back-end wine database owned by the winemaker, the transaction record will then be updated automatically.

A system structure flow chart of the NAS along the supply chain of specific wine is shown. In fact, the NAS comprises FIVE important controllers to perform different functions, which are the 1) Supply Chain Information Controller, 2) Transaction History Controller, 3) Authentication Controller, 4) Wine Pedigree Controller, and the 5) Unsuccessful Record Controller, which were all setup in the back-end database.

The Supply Chain Information Controller is responsible for collecting and managing company information, record of past collaborative projects with the winemaker and the wine has been held by the supply chain partners. For example, the information, such as the combination of wine products involved, of the collaborative project could be updated simultaneously when those wine products were being sent by the winemakers throughout the supply chain and accepted by the subsequent supply chain partners through reading the NFC tag attached, with ScanWINE running on their NFC-enabled device. The information should be pre-registered by the supply chain partners and
verified by the host company before the first transaction record was sent to the Wine Pedigree Server.

The Transaction History Controller is crucial for the wine pedigrees because they form the entire picture of the product history of wine in specific nodes of the supply chain, for which it will collect and manage all the nodal transaction history including wine information and release records provided by the winemakers and those transaction records and even the sales records provided by subsequent supply chain partners; it also forms the basis for tracing problems when suspected counterfeits emerge. As the wine products move along the supply chain, each supply chain partner should read the NFC tag affixed on the wine bottleneck using their NFC-enabled device, supposedly connected to the Internet with JSON through HTTP with the Transaction History Controller, so that each nodal record could therefore be updated, which in turns the aggregated information stored in winemaker's wine database could be updated, automatically, under which no one, but the winemaker, could modify the transaction record manually, which is also a security consideration of the NAS.

The Authentication Controller verifies those nodal transaction histories and those updated supply chain information from the Transaction History Controller and the Supply Chain Information Controller respectively. The Authentication Controller screens out suspicious activities along the supply chain; such as the NFC tag on the wine was not the original one and being found. The screened records are then sent to the Wine Pedigree Controller for storage and being accessed in the Wine Database Layer. For those wine records, which could not pass through the Authentication Controller and being regarded as a suspected wine counterfeit, the “Wine Status” of that wine would be turned from “Valid” to “Invalid” when the “WID” (component of Tag Value) stored in the NFC tags scanned, by the supply chain partners or wine consumers, was found unmatched with that in the back-end database owned by the winemakers, the related wine record will be sent to the Unsuccessful Record Controller for storage, for further review and future reference by other supply chain partners shared by the corresponding winemaker. The supply chain partners will also be responsible for reporting such a case to the winemaker and sending the “Invalid” wine back to the original winemaker for fear that the suspected wine counterfeit will still be existed in the market. Nonetheless, the “Invalid” wine record stored in the Unsuccessful Record Controller will also be shared to the Supply Chain Information Controller to update the record under a specific wine supply chain reporting the suspected case of wine counterfeit, for further documentation and reference of the winemakers.

The supply chain partners can also verify the partial wine pedigree from the point of manufacturing to the previous owners, throughout the supply chain, by making requests to the Wine Pedigree Controller storing the legitimate wine records, which in turn retrieved transaction records from the Transaction History Controller as well as company information from the Supply Chain Information Controller to generate the required pedigree from the Wine Pedigree Controller. They should reject any wines with a suspicious partial pedigree referring to the server. Besides, the Wine Pedigree Controller and the Authentication Controller are also responsible to work together, in which the former storing partial legitimate wine record while the latter is
comprised of a series of business logics for verifying wine record, on generating completed wine pedigrees, receiving request from those users of NAS and responding to it with JSON data format to their NFC-enabled devices for transferring the anti-counterfeiting value. When a wine consumer is satisfied with the genuine wine through using the NAS and has paid for it with confirmation, the NAS will automatically update the sales record to the Transaction History Controller, which will subsequently be sent to the Wine Pedigree Controller. It turns out that the tag would be no longer workable and any further reading processes detected with the same wine after the sale record updated, will be deemed suspicious.
4.4 Use Case Analysis of the NAS

Considering the whole NAS, there will be mainly three web application systems contributed to make the whole NAS available, which are the web-based wine database storing those important wine details, the app named TagWINE in which winemaker could utilize the app to write the specific wine record into the NFC tag while performing bottling in the wine production processes, and the ScanWINE in which both the supply chain partners and the wine consumers could use the app to authenticate a wine before accepting a wine from the winemaker or the previous nodes along the supply chain by the supply chain partners or buying the wine by the wine consumers at retail points.

There are FOUR users will well be involved in the system, which are the winemakers, supply chain partner, wine consumer and the unregistered users. According to the Use Case Diagram below, the web-based wine database could only be accessed if both the winemakers and supply chain partners registered so that they could access the system for usage; however, only the winemaker, which is also the administrator of the system could perform functions such as create, edit or delete on every wine, project and the partnership records stored in the wine database (even those owned by the registered supply chain partners), implying that the wine database owned by the supply chain partners is just the extension of that owned by the winemaker in which the registered supply chain partner could only read, search or even sort those records related to the specific winemaker and they have no right for modifying any single record owned by that winemaker. For the TagWINE, the green-highlighted area states that only the winemaker will be eligible for accessing the app to perform tag-writing and other functions with the app.

For the ScanWINE, actually, any user could utilize the app, including those unregistered users, the supply chain partners and the wine consumers to perform function to authenticate a wine along the supply chain, distribution channel and even at the retail points with required wine records returned. However, the logged-in users area states that the functions such as buying, accepting the wine, sharing to others and even manually checking the NFC tag ID with the winemaker’s database will only bound for the registered supply chain partners and the registered
wine consumers to use, under which the activity history for individual account should only be accessed if the corresponding registered user is logged in so that those histories could therefore be viewed by the account users.
Chapter 5 – The Web-based Wine Database Architecture

5.1 The Design of Database System Sitemap

The sample database was designed and constructed based on a hypothetical winemaker, called The Natural Wine Company, to convey the idea that the NAS is based on only one winemaker who is the only host of the back-end wine database, instead of a cluster of winemakers, in this final-year project. As the heart of the NAS, the web-based wine database owned merely by the winemaker is the place where all the wine records would be stored. The processing of wine records such as creating, editing and even sharing with to the registered supply chain partners will all take place here. For this web-based database, in addition to those wine records stored for the purpose of being requested by those supply chain partners and wine consumers while they accepted and even purchased the wine throughout the supply chain from the Wine Pedigree Controller, the database also stores invalid wine record of a suspicious wine found throughout the supply chain from the Unsuccessful Record Controller, and those information of trusted supply chain partners with their associated projects involving a combination of wines produced by the same winemaker, from the Supply Chain Controller.

For the Site Map of the database, all the functions that would well be appeared on the web-based database, were divided mainly into 4 tabs on the site which were Active Wine, Inactive Wine, Project Details and information of Supply Chain Partner respectively. For those functions, the natures of them were mainly the searching for targeted wine records, sorting the lists we have with different attribute in different sequential preferences, functions like editing, creating new wine records helping the development of specific works, as well as deleting unnecessary records, could be carried out all in once the lists of wine, project and the partner records were visited. The sharing functions of designated wine record could be achieved under the views of wine records such as the webpage of “View Details” or the “Edit”. Besides, a login page will also be designed and required for winemakers’ login so that only the winemaker could get access into the database; the page for registration of login was also designed in case the winemaker has never been to the web-based database before.

For the tab of Active Wine, it allows winemakers to enter the wine they are going to produce or bottle, entering details of wines, performing functions like searching the wine record they needed, sorting to customize the sequence of the list of wines, and even view the full pedigree of specific wine so that the winemakers will have a better understanding on wine status and comparison between different wines whenever there will be editions of wine records needed to be made by the winemakers. It follows that the winemaker could therefore have a better planning of their wine products and better management on those associated wine records, projects and increasing the effectiveness on the projects they will be working with their trusted supply chain partners later on, since the details of those individual wines involving in certain project could be
viewed and deployed easily to a specific supply chain partner. All the wine records listed in the tab are actually extracted from the Wine Pedigree Controller.

For the tab of Inactive wine, it allows the winemaker to list down all the “invalid” wine records of the corresponding suspicious wine counterfeit being spotted throughout the supply chain in which the wine pedigree could not pass through the Authentication Controller. The same functions deployed at the tab of Active Wine could also be performed for specific operation, such as searching with specific requirements like the vintage of the wine, the sorting function to customize the sequence of wine records on the list, and viewing details of the invalid wine pedigree, so that the better reviewing processes could carried out by the winemakers later on with the suspicious wine return by that supply chain partner spotting the issue. The invalid wine record is actually from the Unsuccessful Record Controller, and be regarded as “invalid” once the wine status changed from “valid” to “invalid” because of the matching process between the data stored in the NFC tag and that stored in the back-end database could not be attained.

For the Project list, the winemakers can create a project including a combination of wines produced my them or a certain quantity of specific wine into it, as well as which supply chain partners and its group the project belongs to. The design of the project list can allow the winemakers have a better planning on their works in different levels instead of only be able to get access of wine record with its full pedigree only, which is only a level of managing wine records, which should be probably spanned into a project with supply chain partners involved eventually for more well-rounded management on those wine and transaction records. For example, if winemakers want to create a project spanned by group of supply chain partners, incorporated with different wines with certain quantity, it is much more convenient for them to manage all of the wines in one go in the system in which they can freely perform those functions like creating wine records, putting it to the tab of inactive wine record, with simply just clicking a button on the web-based system. For sharing functions, like sharing a specified wine to targeted partners, could also be performed easily as well.
While for the tab about the details of Partner information, winemakers can create the contact of their trusted supply chain partners, who should also suppose to register to the winemakers so as to being shared with the associated wine records while the wine will be accepted by the, inside database system, entering details like their name, business registration number, email address, mobile phone number, etc. And there are some amazing functions like we can add some wines, involved with certain supply chain partners, under the contact of supply chain partners we created, so that it can be possible to choose which wine we want to share to a specific targeted supply chain partners, and it follows that the targeted partners could retrieve the shared wine once they logged into the system again after the wine is physically traded to that supply chain partner, if the contact was registered and created. How winemakers share the wines to their partner is simply clicking the sharing button and selecting which one to share, inside pages like “Create” or “Edit” under the tab of active wine record in the sitemap, and then the sharing behavior will be achieved automatically when they login to their own supply chain database system afterwards. All the details about the projects and about the supply chain partners are actually stored in the Supply Chain Controller. The full picture of the System Sitemap, Entity and Attribute Diagram and Entities Relationship Diagram are included in Appendix 5, 6 and 7 respectively.

For the database content design, there will be around five steps we need to take so as to ensure the web-based wine database problem-free and more efficient, which are identifying the Entities with its attributes, Relationships, Keys, the corresponding data type of each column of data stored in the entities table, and the normalization taken for specific entities. The processes of database content architecture involve structuring and organizing content on the web-based database to enable the winemakers and even the supply chain partners better locate the data they want. The content architecture is vital to a well-design and efficient database and should also be natural and intuitive for the winemakers and the supply chain partners who will suppose to have their own version of database connected with that of the winemakers for sharing purpose on specific wine record. It is also better design the users involved of the web-based database as soon as possible as different users have varying needs and behaviors online, the database needs to accommodate these needs and behaviors nicely. The details of the database content design will be demonstrated in Appendix 8.
Chapter 6 – The Android Applications Architecture

The Cordova provides a set of uniform JavaScript libraries that can be invoked, with device-specific native backing code for those JavaScript libraries. Cordova is available for the following platforms: iOS, Android, Blackberry, Windows Phone, Palm WebOS, Bada, and Symbian. As such, the Cordova Native Library, Android Framework and the SDKs could therefore be adopted and called for building both the ScanWINE and TagWINE of NAS, which are both Android App and running on Android 4.3 OS. Most importantly, the apps built with the PhoneGap API could include the NFC Plug-ins so that both apps could be NFC-enabled and utilized the NFC technology of the smartphones. *Please view the Appendix 9 for more details.*

6.1 The Introduction of NFC-Plugins and its API

Through including the NFC-Plugins into the ADT with the PhoneGap API, the files will be placed under the “src” as “NfcPlugin.java”, and there are lots of activities designed with Java. Another API, named “phonegap-nfc” will also be included in which the API includes all the events of formatting an NDEF tag. The phonegap-nfc plugin actually allows functions of reading and writing NFC tags from a PhoneGap application using JavaScript, under which the NFC-plugins will be activated once the following statement added to the “config.xml” of the projects of both apps.

```xml
<plugins>
  <plugin name="NfcPlugin" value="com.chariotsolutions.nfc.plugin.NfcPlugin"/>
</plugins>
```

Another API, named “phonegap-nfc-simplenfc” was then built based on the “phonegap-nfc” mentioned. Indeed, there are only two function and two objects constructed under the API. The function, named “function MyObj(string_mimeType)” is actually defining a public instance variable and made it to be MIME type, while the “function failure(reason)” was also deployed for fear that there will a failure case during tag-reading process. For the two objects, which are “MyObj.prototype.startListenForNFCRead” and “MyObj.prototype.writeNFCData” as shown in the following, the former is actually for the ScanWINE in which there should be string of recordType and payload (NDEF message/ the tag value) returned during the NFC-reading processes, while the latter is for the TagWINE in which a specific string data (tag value) will be written into an NFC tag. The conceptual notions on how NDEF message and payload is like, and the formatting structure of an NFC tag could be are all included and shown in [Appendix 4](#).
The reason why it was said that the “phonegap-nfc-simplenfc” was built based on the “phonegap-nfc” was that actually the “phonegap-nfc” includes all the formatting functions (events) about NFC tag, both the objects mentioned in the “phonegap-nfc-simplenfc” was designed to call and include some of the functions defined in the “phonegap-nfc”, which are “nfc.NdefListener” and “nfc.write”. For the “nfc.NdefListener”, it is actually a function that registers the callback for NDEF event, under which the “callback” means a callback will be called when an NDEF tag was read, the “win” and “fail” mean the callback will be called once the listener was added and if there was an error respectively for the “phonegap-nfc”.

For the “nfc.write”, it is actually a function that writes an NDEF message (tag value), which is an array of one or more NDEF records as mentioned in the above, to a NFC tag, under which the “ndefMessage” means the array of those NDEF records, while the “win” and “fail” in “phonegap-nfc” mean the callback will be called when the tag was written and if there was an error respectively.
Furthermore, the reason why the required NDEF event will start is because there should be an “event handler” to determine whether the event would start or not. For instance, the “function onTagIsRead (nfcEvent)” for the object of “MyObj.prototype.startListenForNFCRead” is actually the event handler under which the required NDEF event will be fired when the NFC tag is being read provided that the event itself is “passive” in nature in which another function will be needed for waking up the “event”; however, sometimes the event handler will not be needed due to the fact the event itself is “active” in nature, like the “nfc.write”, which can be carried out the NFC-writing process for writing the “byteData” into the “message”. In short, the event-handling function is to handle the NFC events if it is “passive” in nature.

As such, with the advent of the NFC-plugins and its associated APIs, objects and the NDEF events, the ScanWINE and TagWINE could therefore perform tag-reading and tag-writing functions with the NFC-enabled smartphone, through calling those objects in the “mainLogic.js” of both apps.
6.2 The Communication between the Server API and Application JavaScript APIs

It is normal that there will be questions about how the required tag value can be returned to both apps for showing, and how the communication between the database server and both of the applications will be like and setup. Indeed, such communication between the server and both apps was actually achieved with applying two APIs in which one from AppController of the server and the other from the “wineappclient” of both apps, namely Server API and Application JavaScript API respectively.

At the “AppController” (server end), there are totally nine functions and an object designed and included in the class in that controller, so that some hashed random tag values could be produced with using both of the functions of “genTagHash()” and “createHash()”, and the logic of showing a specific array of wine records was also included into some functions such as “getAllWine()” or “getWine()” so that all the required wine data could be fulfilled those wine record request sent mainly from the TagWINE.

Some required wine record data by the apps could be formatted as JSON Output so that it can be called back by those objects at the JavaScript API from the application end and being displayed on both ScanWINE and TagWINE, if the wine itself is still “valid” for its wine status, through using “Object formatAsOutputJSON()”, in which all the required data, such as the “wineTitle” or “WineCategory”, could be returned with an array containing all the element data of the wine records. If there is any order those data being returned to the application end, like the one specified, this method must return or the involving wine data in the same order as specified. The returned array will be “safe” in that the object itself will maintain no references to it. The caller is thus free to modify the returned array. This implementation allocates the array to be returned, and iterates over the elements in the collection, storing each object reference in the next consecutive element of the array, starting with element 0.
At the end of the Application JavaScript API, the API is actually one of the JavaScript files, named as “wineappclient”; first of all, a function with the public instance variable was built so that the URL of the web-based database could therefore be referred and prepared for a series of subsequent callback activities from the application end. In addition, there is also a private function, named “function SimpleAjax()” setup so that the Ajax callback method could be well-defined before the those callback activities for the wine data required were carried out. The function itself is actually “private” in nature, which is a private sharing method, in which it can only be called within the class; the setting will be done once the type, url, data, data type and those functions referred to if the callback is succeeded or not.

Once the private sharing method is set and applied to all the “public” sharing objects directly called back wine data from those functions at server end, under which the callbacks from those public sharing objects will request callback of the required wine data based on the AJAX method set in the “function SimpleAjax()”; for instance, all the required wine data will be called back with the data type of JSON and all the subsequent events performed if the callback will be succeed or not, are all specified in the functions, namely “successCallBack” and “failCallBack” respectively.

All the objects included in the Application JavaScript API are actually “public” in nature under which it can be called beyond the local classes and able to be called by those functions in the “mainLogic.js” of the project, so that specific functionalities of the apps could thus be achieved. There are actually six objects in the Application JavaScript API, which were all already deployed with callback events so that the involving and required wine data, generated from those corresponding six functions in the Server API (AppController), could therefore be returned back to the objects with JSON. The corresponding callback relationship diagram between the two involving APIs at server end and application end is shown as shown as follows.
Generally speaking, the reason why an object at application end could call back wine data from the corresponding function at server end is actually based on the synchronization of the variables and even the action set at the application end, which in turns must be referred to same function at the server end. For instance, the object of “MyObj.prototype.ConsumerBuyForWine” at application end, with the action defined, which is exactly the function named “ConsumerBuyForWine” at the server end. The callback could therefore be reached, and the required wine data, which are “isBuySuccess”, “reason” and “wine”, could also be returned in JSON with the help of the function of “formatAsOutputJSON (wine)” and be utilized by the “mainLogic.js” if the public object will subsequently be called.
There is another example, like the object of the “MyObj.prototype.getWine” at the application end with an action defined with “getWine”, which is exactly referring to the function of “getWine ()” included in the “AppController” at the server end. There is also a situation that the function will return nothing back to the corresponding object at the server end in case the wine is actually equal to “null”. The callback was therefore be reached and the required wine record will therefore be returned back to the application end for further external calls by the “mainLogic.js” of both apps, ScanWINE and TagWINE.

```javascript
//function_successCallback(isFound,wine);
MyObj.prototype.getWine = function(int_wid, function_successCallback) {
    console.log("getWine, id = "+int_wid);
    var self = this;
    var action = 'getWine';
    var JSONData = {id:int_wid};
    var successCallback = function(respon){
        var wine = respon.wine;
        var isFound = (wine != '');
        function_successCallback(isFound,wine);
    };
    SimpleAjax(self,action,JSONData,successCallback,self.errorCallback);
};
```

```java
public ActionResult getWine(int id)
{
    var wine = db.ActiveWines
        .Where(x => x.WID == id)
        .Select(x => new
        {
            WID = x.WID,
            WineTitle = x.WineTitle,
            WineCategoryName = x.WineCategory.WineCategoryName,
            Producer = x.Producer,
            Country = x.Country,
            Vintage = x.Vintage,
            Price = x.Price,
            WineTransactionHistory = x.WineTransactionHistory,
            WineDescription = x.WineDescription,
            WinePic = x.WinePic,
            TagID = x.TagID
        })
        .SingleOrDefault();
    if (wine == null)
    {
        return Json(new { wine = "" });
    }
    return Json(new { wine = wine });
}
```
6.3 The Tag-Writing Android Application – TagWINE

This is a component of NAS, enabling solely the winemakers to write view or edit those wine records into those selected NFC tag while performing bottling in the wine production processes at the winery. Apart from the writing/editing functions, the app also allows the winemakers to view the wine details while using the app, and to check the previous activities history like those writing and editing history.

The approach of building both the TagWINE and ScanWINE was actually Object-oriented Programming (OOP), in which objects (data and code) were built in different APIs under the application project folders and the object itself is actually a modular and reusable element which could be called within a class, from functions of other API under the same project folder, and even the “mainLogic.js” of the application. Through building the applications with using the approach of OOP, the structure of different API and even the whole programme could be more easily understood, maintained, debugged and even be further improved in the future in case there is any new functionality needed to be added to the apps.

Based on the concept of OOP, both applications were actually built with mainly the “mainLogic.js” calling those objects in the APIs, for instance, there are actually two core APIs, which are very crucial on whether both applications could call back required wine data from the Server APIs and adopt NFC functions from the NFC API (simplenfc). As such, objects in “wineappclient” were built so as to enable the “callback” relationship between those functions in the “AppController” (Server End) and the “wineappclient” (Application End), while those objects in the “simplenfc” (NFC API) were constructed so that some of the events in the original NFC API – “phonegap-nfc” could be included and enabling the NFC-reading and NFC-writing functions of the applications running on NFC-enabled smartphone.
What the “mainLogic.js” for both the applications were about was that those related objects in the aforementioned APIs would be called by the functions in the “mainLogic.js”, since they are all “public” in nature, whenever there is a set of specific functions needed to be carried out by the applications, all the required data retrieved by the objects will go through the business logic in the “mainLogic.js” and then pass to those right-hand-side HTML files for display.

Speaking of “mainLogic.js”, both applications will define the following at the beginning of the JavaScript file; for example, the “SERVER_URL” will be defined so that the application can therefore connect to the server end whenever the objects, called by the functions in the “mainLogic.js”, make wine data request to the back-end server based on the Uniform resource locator (URL) registered. The APIs were also defined so that it constituent objects could be called by the functions later on.

```javascript
var SERVER_URL = "http://imse2016.imse.hk:45678/NFCWine2013";
var MIME = 'nfcwine/tag';

function onQueryDataError()
// navigator.notification.alert('', function() {}, "Ajax fail to call server");

//Our low level module instance
var simNFC = new NFCsimulator(MIME);

function onTagScanned(tagValue) {
    console.log("Scanned tag value: " + tagValue);
    wineServer.ConsumerFindForWine(tagValue, onWineIsFound);
    navigator.notification.vibrate(1000);
}
```
As such, for the function “onTagScanned ()” in the “mainLogic.js”, the object, named “ConsumerFindForWine(tagValue, onWinesIsFound)”, was being called by the function from the wineappclient API (which was assigned as “wineServer” at the start), so that a series of callbacks on requesting wine data, such as “nextNFCTag” and “isInCommit” could therefore be achieved with the server end.

The general construction structure of the TagWINE is actually shown in the Module Relationship Diagram. For the “mainLogic.js” of the TagWINE, there are totally eight local functions included so that the mechanism like how the required wine data could be located for displaying before tag-writing process, how to write a tag value into a NFC tag and even how to make a list showing all the wine record stored in the wine database available for tag-writing processes, could all be achieved by calling public objects from other APIs under the same project folder. For instance, the function “writeTagFor ()” will call the object “MyObj.prototype.writeNFCdata” so as to perform the tag-writing process with using the NFC technology by telling the smartphone to do so through using the TagWINE.
6.4 The Tag-Reading Android Application – ScanWINE

This is also one of the important components of NAS, enabling both the supply chain partners and the wine consumers to authenticate a wine along the supply chain during the wine transfer procedures and before purchasing the wine at the retail points before paying for it. The app allows those users to scan the tags attached on the wine bottleneck with NFC technology with using the NFC-enabled smartphones or devices. Apart from the functionality of scanning with NFC tags, the app also allows the user to perform functions such as accepting the wine from the winemakers or even the previous node of supply chain during the wine transferring process performed by the supply chain partners, or buying the wine while the authenticity of the wine was confirmed. Functions like sharing to others, manually checking the NFC tag ID with the winemaker’s database, and checking the out the activities history like last scanned wine, could all be available once the users is registered an account.

For the ScanWINE, the application was also built based on the OOP as aforementioned, in which all the elementary objects, enabling the callback mechanism with the server end and the NFC tag-writing and tag-reading function functions, were all built and included in mainly two APIs, which are “wineappclient” and “phonegap-nfc-simplenfc”, which will well be called by the local functions in the “mainLogic.js” of the ScanWINE, whenever there will be an event needed to be performed relating to the object, such as the NFC-reading process.

As shown in the Module Relationship Diagram of the ScanWINE, there are 4 local functions included in the “mainLogic.js”. For example, the function “mainLigicinLit()” will call the object “ConsumerFindForWine” from the “WineAppClient” API and both “startListenForNFCRead” and “writeNFCData” so that the specific wine record could be located, the tag-reading process and the tag-writing process could be carried out through using the ScanWINE, and the reason why there should be a object “writeNFCData”, although the ScanWINE is mainly for tag-reading process, is that the “Read Count” methodology
was introduced after the first demonstration as improvement, under which the tag value needed to be updated to the NFC tag every time after the tag-reading process. All the required and processed wine data will then be passed to those HTML files based on the following syntax included in the “mainLogic.js”, and will then be displayed while running the ScanWINE on the NFC-enabled smartphone.
Chapter 7 – The Anti-Counterfeiting Mechanism of the NAS

It is too early and naive to say that the NAS will be the most secured anti-counterfeiting system adopted ever in wine industry to relieve the growing wine counterfeit market, or rather, what the NAS transferred is the notion that it can add one more layer of security to those wine products in the market based on those anti-counterfeiting technologies already adopted on the wine bottles. But, why the NAS can provide anti-counterfeiting and security values in today’s wine industry? The proposed NAS performs wine anti-counterfeiting by maintaining supply chain integrity, not manually but automatically, the significance of which is twofold. Firstly, the transaction path of a wine is clear and its source can be traced accordingly with the data stored in a series of servers; secondly, wine authenticity can be validated off-hand with one’s own NFC-enabled devices with applications developed and owned by the specific winemakers. But we all have to bear in mind a fact that NAS is always possible to be attacked, and we should try out utmost to make it with least chance to be attacked.

The back-end wine database owned by the winemaker is the heart of the proposed NAS, connoting that only the winemaker would be allowed to create, edit and delete any wine records, information about the trusted supply chain partners and the details about project involving different combinations of wine products. There will be no right for any other related industry players to modify any column of a wine record stored in the system through the HTTP, like using their own wine supply chain database to connected with the one owned by the winemaker of specific wine, when using the applications. However, there is only one situation that the wine record stored in the winemaker’s wine database, could be accessed and even be updated; for instance, the transaction record of a specific wine could be updated when it was accepted by the next node of supply chain from the winemakers, like the distributor, or being sold to the wine consumers once the online payment, integrated with the NAS, was confirmed. In these situations, the machines will update the new status like “wine being accepted by” or “wine sold” automatically, with JSON through HTTP, without any human intervention during the whole updating process of the wine for fear that some of the supply chain partners may doctor the wine record causing even more wine counterfeit in the market.

The wine details, and the full pedigree of the wine with the transaction records along the supply chain, stored in the host server of winemakers could only be accessed or retrieved while the NFC-enabled devices and the controllers of host servers of winemakers, like the Wine Pedigree Controller and Authentication Controller, are being connected through the internet using JSON data format, under which machine-to-machine communication, which is the communication between the ScanWINE running on the NFC-enabled devices and the Application Controllers of the back-end server, will be carried out without any human intervention and errors, making manual modification of supply chain partners or wine consumers would not be a factor causing system failure. Although one of the integrated features of the NAS is that the wine record could be shared to the next node of partner along the supply chain once the wine and its intelligence were being
accepted, the data shared to the suppliers’ databases could only be viewed, without any right for any manual modification on it. With the growing popularity of Internet connection with HTML or JSON, and NFC-enabled smartphone or device being more common in the market place, the NAS could be more mature to allow wine consumers to check the wine pedigrees they would like to purchased, integrated with e-payment system and behavioral suggestions system installed in the NAS.

Regarding the wine consumers, making sure that the wine products are genuine protects their own safety and guarantees value for money. There are indeed sufficient incentives for them to verify the authenticity of wine with their own smartphone, given a convenient-enough way to do so. Similarly, since wine product without a plausible history may not be saleable to the next carriers or the wine consumers at retail points, the current carriers bear a responsibility in returning the suspected wine spotted with problems while reading the wine with NAS. In anticipation of the enhanced customer confidence, it would be justifiable for the winemaker to host the NAS. The wine producer, who is also the server-hosting company, is responsible for tracking and recording suspicious transactions and tracing through the sources of security breaches in the various supply chains as the wine products move along the supply chain.

Specifically, how do the components, like the applications named ScanWINE and TagWINE, the NFC Tags and the back-end wine database owned by the winemakers, of NAS transfer the anti-counterfeiting value in details? For example, how are they set up so that the counterfeiters could hardly make attacks to the NAS? This mechanism hinders counterfeiters from attacking the NAS or cloning the NFC tags because of FOUR reasons: 1) the secured setup on NFC tag, 2) setup of the automatic updating system on both the applications and database system, 3) the security features on NFC tag and its deployment and the 4) the procedural setup of the NAS.
Chapter 7 – The Anti-Counterfeiting Mechanism of the NAS

7.1 Secured Setup on the NFC Tag

Referring to the details of what the NFC tag stores under the NAS, actually, only the data of tag value (WID+readCount) of a wine will be encrypted, in case the NFC tag is Ultralight C, which is 3DES Encryption-protected, and stored in the NFC tag after the NFC tag is being formatted with NDEF messages, instead of encoding, encrypting and storing every single column of wine record in the tag. Currently, industry players using RFID technology for anti-counterfeiting purpose are actually putting every details of a product record into the tag, in which we named it as an Off-line Data Tag that is highly susceptible to those attacks such as spoofing, replay attacks, repudiation, etc.

The use of Off-line tag can easily lead to system failure and even collapse, making it even more susceptible to wine counterfeiting. However, for the situation of NAS, the tag value is the only data stored in the NFC tag and act as an only key to link up those application and the application controllers of the back-end wine database for communication. With only the tag value stored in the NFC tags, that tag must be an On-line Data Tag in nature, which is more secured for sure, in which updating a column of data of a specific wine record at the database’s end would in turn be demonstrated with an updated record on the application running on an NFC-enabled smartphone, whenever an NFC reading process is carried out using the ScanWINE, instead of putting all the details of a record into a tag, which will be vulnerable to attacks and not convenient as updating processes could only be done if the wine sent back to the winemakers for further updating processes. For instance, if the data of “winetitle” named as ABC in database, and you perform modification on the database, the updated “winetitle” would be shown on the ScanWINE next time when you perform reading process on the NFC tag attached. It turns out that the tag value is the only data the NAS needed to protect for.

Undeniably, it is also unsafe if we only put the “WID” and “readCount” in the NFC tag and make it visible to the public, though the tag value will be hashed later on at the improvement stage, as it will in all likelihood be susceptible to the attacks as well. So as to strengthen the security on the NFC tags and the NAS as a whole, the data type of WID has been altered from “integer” to “uniqueidentifier” and it is believed that the “uniqueidentifier” data type is far more secured than the purely an data type of “integer”, in which the uniqueidentifier data type stores 16-byte binary values that operate as globally unique identifiers (GUIDs). A GUID is a unique
binary number; no other computer in the world will generate a duplicate of that GUID value. The main use for a GUID is for assigning an identifier that must be unique in the whole computer network. Because GUIDs values are long and obscure, they are not meaningful for users. If randomly generated GUIDs are used for key values and you insert a lot of rows, you get random I/O into your indexes, which can negatively impact performance. GUIDs are also relatively large when compared to other data types. In short, the data type of “uniqueidentifier” to be the most special one and there will no chance for duplication of WID when the spoofing attack happened on NAS.

However, the NAS is also possible to be attacked even though the data type of WID was being set with “uniqueidentifier”. The WID was then considered to be hashed with hashing algorithms, named MD5, and make it no meaning at all and not possible for any attacks involving spoofing or peeking the WID and the “readCount” stored in the NFC tag. Hashing algorithms are usually cryptographic in nature, but the principal difference is that encryption is reversible through decryption, and hashing is not. While it is not possible to take a hashed result and "dehashed" it to get back the original input, hashing functions are typically created to minimize the chance of collisions and make it hard to produce the same set of hashed values again. As such, only the winemaker will know the “secret” which is the tag value (WID+readCount) linking both the application and the back-end wine database together for performing functions such as record request or record retrieval.

There are also two columns of data set, which are “TagID” and “TagStatusID” under the database table of “ActiveWine” making the NAS a more secured system in the market. For the TagID, it actually stores the ID of the NFC tag as every NFC tag is born with an ID. With the data of TagID returned from the database and visibly shown on the ScanWINE, the supply chain partners and even the wine consumers can key in the shown TagID and see whether there will be any matching result of the same TagID returned from the database, to verify that if the NFC tag is actually not born with the wine since the bottling process, in order to prevent counterfeiter putting fake tag on the second-hand wine bottles. While the “TagStatusID” is actually binary in terms of data type and default as “0”, under which when the NFC tag is being wrote in data with the use of app named TagWINE, it will turn to be “1”. If that is the case that the “TagStatusID” is now turned to be “1”, there will be no such record shown on some tag-writing application and being unable to write anything into it again. In short, the introduction of the TagStatusID prevent the wine record from being wrote again and again into that NFC tag, and it could only be wrote once under which “TagStatusID = 0” means writing process is available while “TagStatusID = 1” means the writing is halted.
7.2 Hashed Functions Adopted for the Tag Value Stored in the NFC Tag

As aforementioned that there is only WID will be written into the NFC Tag which will in all likelihood be far more secured than storing more wine attributes beyond only the WID; besides, the above improved “Read Count” security system should also be stored in the NFC tag so that the functions could change the tag value every time it is being scanned by the ScanWINE. There are actually 2 functions so that the tag value (WID+readCount) could be generated with using the Message-Digest Algorithm 5 (MD5) to generate hash codes. For the function of “genTagHash(int win, int readCount)”, all the WID and readCount were standardized with data type of “string” and being combined to form a string named “toHash”, representing the “compound” stored in the NFC Tag, while the “toHash” will then pass to the function of createHash(). For the function of “createHash(string stringToHash)”, there were steps done, so that every data generated from this function will be a group of 32-byte random numbers and no visible meaning at all for those intended to copy the “compound” stored in the NFC tag, which are 1) adding a set of random number named “salt” to make the hashed chunks even more complicated, making counterfeiters even harder to guess, and 2) calling the MD5 with hashed algorithm to generate a hashed chunk from the salt and the “compound”, and all the things together are actually generating a hashed tag value stored in the NFC tag, for which it will update whenever the tag is being scanned.

```csharp
private string genTagHash(int win, int readCount)
{
    string win_str = win.ToString();
    string readCount_str = readCount.ToString();
    string toHash = win_str + readCount_str;
    return createHash(toHash);
}

private string createHash(string stringToHash)
{
    string salt = "124j29059890Bnfw68 adapter8908c89b2Q9343ttjdg9s8a7f9a7v9fe8w5ver";
    string toHash = stringToHash + salt;
    return string.Join("", MD5.Create().ComputeHash(Encoding.ASCII.GetBytes(toHash)).Select(s => s.Tostring("x2")));
}
```
7.3 The “Read Count” Methodology

So as to improve the NAS to be more secured regardless of those security features already included in the NAS, a philosophy named “Read Count” was introduced with those hashed tag value produced during the process to reach the purpose. To achieve this, first of all, there were two new entity tables added and the entity table of “ActiveWine” altered based on the existing data model, which are named “TagUpdateTransaction” and “TagValueAchieve”. The former will be used to store all the “old_tag_value” and “new_tag_value” generated during every tag-reading process, while the latter will store the “old_tag_value” after each tag-reading process as a “tag_value” for purpose of comparison later on.

With the advent of those hash-generating functions deployed in the “AppController” of the wine database, which are “createHash()” and “genTagHash()” respectively, a 32-byte hashed “NFCCurrentTag”, which is the value stored in the tag, will be first generated and returned after the tag-writing process using the TagWINE, and there will also be a new 32-byte hashed “new_tag_value” generated and returned with the required wine record after each of the tag-reading processes using ScanWINE. All the tag values such as “NFCCurrentTag”, “old_tag_value” and “new_tag_value” are actually a hashed combination of “WID” and “readCount”, which will be the only “compound” stored in an NFC tag. To a certain extent, the incremental readCount can contribute to prompt a “new_tag_value” generated every time after a tag-reading process, as it is a constituent of the “new_tag_value” and it will be a different numbers (added by one after every tag-reading process) making the “new_tag_value” in turns to be different as well.

Provided that there is no matching result of the “new_tag_value” with those “tag_value” already stored in “TagValueAchieve”, there will then be a tag-updating command sent to the server, under which the “new_tag_value” would therefore be assigned as
“NFCCurrentTag” and stored in the ActiveWine, the “old_tag_value” will be stored in the "TagValueAchieve" as "tag_value" for the comparison for the oncoming tag-reading process, and the readCount will be added by one as well. The communication map and the flow chart of the "read count" was shown better understanding.

However, we all knew that the tag value stored in the NFC tag will be updated after every tag-reading process and therefore, there will be two important cases to note when the process comes between step 5 and step 6 in case there will be a disconnection or failure of communication somehow happened during the tag-reading process; for instance, the first case could be the situation that the “new_tag_value” could not even be updated and overwritten to the "NFCCurrentTag" stored in that NFC tag, leading to failure to commit the update tag value back to the server and the “old_tag_value” will then still be sent to the server if there is any coming tag-reading process. The second case would be the situation that the NFC tag itself was updated with the “new_tag_value” overwrote the “NFCCurrentTag” stored, but somehow, due to the disconnection, the change of “NFCCurrentTag” is failed to commit back to the server, leading to the tag value stored in the tag and server will not be synchronized for oncoming tag-reading processes. Both two cases will well lead to chaos of the tag values stored in the tag and the server,

```javascript
var isOldNFCCtagInUpdateTransaction = db.TagUpdateTransaction.Any(x => x.old_tag_value == NFCTag);
if (isOldNFCTagInUpdateTransaction)
{
    var returnWine = formatAsOutputJSON(wine);
    return Json(new { wine = returnWine, nextNFCTag = newTagValue, isCommitted = false });
}
else
{
    // create new tag update transaction in database
    var tagUpdateTransaction = new TagUpdateTransaction();
    tagUpdateTransaction.old_tag_value = wine.NFCCurrentTag;
    tagUpdateTransaction.new_tag_value = newTagValue;
    tagUpdateTransaction.wine_id = wine.wId;
    db.TagUpdateTransaction.Add(tagUpdateTransaction);
    db.SaveChanges();

    // return the required wine data back to the app
    var returnWine = formatAsOutputJSON(wine);
    return Json(new { wine = returnWine, nextNFCTag = newTagValue, isCommitted = false });
}
```

Case 1
and influence the security of the NAS turns out. There were functions then deployed in the “AppController” of the database, so that the ScanWINE could continue the NFC tag-updating process with “new_tag_value” as if the first time you proceed to the tag-reading process for the first case, while for the second case the app should be continuing to commit the update during the following tag-reading process.

Also, that is the reason why we need a separate table, named “TagUpdateTransaction”, to store the intermediate tag value change, which are “new_tag_value” and “old_tag_value” of the scanned wine such that whenever there is someone try to scan that uncommitted wine tag again. With the advent of entity tables like “TagUpdateTransaction” and “TagValueAchieve”, the specific wine record will turn to be “Invalid” in case there is a matching result of “NFCCurrentTag” (old_tag_value) and every “tag_value” (stored in the “TagValueAchieve”), under which only more than one tag storing the same tag value will happen with this situation. **It follows that the “readCount” could prevent the wine market from having a NFC tag storing with the same tag value simultaneously.**

Indeed, there will be an “new_tag_value” generated, which will also be assigned to the “NFCCurrentTag” and stored in the entity table of “ActiveWine” after every tag-reading process, and the “NFCCurrentTag” from the most previous reading process (like last reading process) will be assigned as the “old_tag_value” of the next reading process as specified. In short, a hashed tag value (WID+readCount) stored in an NFC tag, would be changed every time the tag is being read and returned with
increasing the readCount by one to, and those “tag_value” (“old_tag_value” from all previous tag-reading processes) stored in the entity table of “TagValueAchieve”, of Cabernet Sauvignon, after the first two reading processes are shown as follows. The ever- therefore changing tag value both stored in the tag and server will make the system hardly be cloned by counterfeiter.

| Cabernet Sauvignon's tag Archive | Cabernet Sauvignon's tag Archive |
|----------------------------------|----------------------------------|
| Tag Value                        | Tag Value                        |
| 4fc3ed54a7879d4a6298e7f20d558151 | 4fc3ed54a7879d4a6298e7f20d558151 |
|                                  | 52020c22120673a2be803151b5b6c7a  |

After FIRST Reading Process

After SECOND Reading Process
7.4 The Automatic Updating System on Wine Records

What does it mean by the automatic updates? It means some of the columns of the specific wine record would be updated simultaneously whenever there is an NAS reading process, performed by both the supply chain partners and the wine consumers, carried out through Internet network with JSON under which the related logic was deployed over the ScanWINE and the “AppController” under the back-end database. There would be only four types of columns in a wine record were made with such function. For instance, the “WineStatus”, which is a status of wine with only two values – “Valid” or “Invalid” with default values as “Valid” when the wine record is first created, could turn from “Valid” to be “Invalid” when two situations happened – 1) the wine is being sold and the payment is confirmed through pressing the button of “Buy it” with the ScanWINE, or 2) the wine moving in the supply chain was suspected as a wine counterfeit and cannot get through the Authentication Controller. Now that the wine was changed with a wine status of “Invalid”, it will be put into the Unsuccessful Record Controller for storage and further reviews by the winemaker.

Some of the programming functions included in the “AppController” of the wine database and the logic performed in the App were amended with adding new elements so that some parts could perform auto-updated features and make the NAS even more secured. For the web-based wine database, if wine status of a specific wine record was changed from “Valid” to “Invalid”, that wine record will be transferred to the tab of Inactive Wine automatically after the change is made, as the “InactiveWineController” in the database was set only displayed the wine record with wine status of “Invalid”. The functionality was displayed using the wine “Cabernet Blanc” as an example.

There were some automatic features were added throughout using all the components of the NAS together, such as the auto-updating functions on the transaction records of a specific wine record with “Today's date + “” + “Write Tag” whenever that wine record was written into an NFC tag, with “Today's date + “” + “scanned” whenever the NFC tag containing with specific wine record
is read by a NFC-enabled devices or smartphones with ScanWINE running onto it, and the following with example states that the transaction record will be updated “Today's date + " + "sold", whenever the wine is being sold, and the wine status of that wine record will therefore be changed from “Valid” to “Invalid” with being transferred to the tab of “Inactive Wine”. (“WineStatusID=1” means “Valid” and “WineStatusID=2” means “Invalid”)

```csharp
public ActionResult ConsumerBuyForWine(string NFCTag)
{
    var wine = db.ActiveWines
        .Where(x => x.WineStatusID != 2)
        .SingleOrDefault(x => x.NFCCurrentTag == NFCTag);
    if (wine == null)
        return Json(new { wine = null, isBuySuccess = false, reason = "Cannot buy invalid wine" });

    wine.WineStatusID = 2; // invalidate wine
    wine.WineTransactionHistory = string.Format("\n\n0 sold", DateTime.Now.ToString("dd-MM-yyyy");
    db.SaveChanges();

    var retWine = formatAsOutputJSON(wine);
}
```
7.5 Security Features of NFC Tag and Its Deployment on Wine Bottle

It is possible to have anti-counterfeiting value through choosing the NFC technology as for the primary and fundamental communication technology for the NAS as mentioned in the previous chapters about NFC technology, so does the NFC tag itself. Some NFC tags are actually born with 3DES encryption, like the Ultralight C, protecting the NFC tag from being wrote, edited and even deleted the data stored into it. As such, there is no one, but the winemaker who sets and knows the password protected the NFC tags, could make any changes and even get access into the editing procedures of the tag.

Besides, the TagWINE, performing functions like writing wine record only for winemakers, will not be available for making it public and for sales on Google Store or any other website on the internet. It follows that only the winemaker could operate the application, which originally designed for them on writing wine record, like the WID, into the NFC tag through the communication between the app and the Application Controllers in the back-end database.

Referring the previous chapter about the deployment of the NFC tag on the wine bottle, the best position to put the NFC tag on the bottle was the bottleneck with foil capsulated the NFC tag into it. Such deployment was also considered as a way to protect the wine from counterfeiting. For instance, once the wine was being bought and uncorked for consumption, the NFC tag storing with tag value, which is an only key connecting applications and back-end database of the NAS, will be completely damaged with the capsulated foil surrounding the bottleneck and the cap, while the wine is being uncorked. Provided that the WID is invisible and not being attacked, the reused bottle for counterfeiting purpose could not be scanned with NAS again, indicating the wine was consumed before.

7.6 Procedural Policies of NAS

With the advent of NAS, the supply chain partners and wine consumers could use their own NFC-enabled device or smartphone to authenticate whether the wine is genuine or not before accepting, sending it to the next nodes of supply chain and even paying for it respectively. There are also some procedures necessary throughout the NAS, in which the supply chain partners have to pre-register before they can be granted to access the host server of the winemaker for NFC scanning processes to update the wine transactions. For this situation, the company particulars of that supply chain partner was actually already included in the Supply Chain Information Controller approved by the winemaker, and they also need to login before using the app of ScanWINE, thus excluding those counterfeiters from attempting to commit wine counterfeiting through using the app to stole wine pedigree, the fake NFC tag and even a second-hand wine bottle.

As mentioned in previous paragraphs, the suspicious transactions would be screened out accordingly if it happens with the situation that the wine records with “Invalid” wine status, the
wine record will then send to Unsuccessful Record Controller as it cannot pass through the Authentication Controller during the NFC reading process. Finally, the supply chain partners and wine consumers will be urged to be aware of wine without a plausible history leading to failed reading process returned with no wine record. The supply chain partners and consumers should refuse to accept, send and even buy for that questioned wine; it is also essential that the related supply chain partners will be responsible for sending the suspicious wine back to the winemakers for fear that the suspicious wine will still be existed in the market, regarding as a wine counterfeit with victims later on.

One of the reasons why the NAS will be more popular in conveying anti-counterfeiting value is that the wine consumers, supply chain partners and wine consumers could simply utilize their NFC-enabled devices or smartphone to authenticate a wine at anytime and anyplace before accepting it or paying for it.
Chapter 8 – The Project Conclusion

8.1 Future Works on NAS

Further Possible Improvements on NAS

Indeed, the development of NAS is actually based only on one winemaker or winery, not to mention that there will be tons of similar apps of ScanWINE, loaded onto consumers’ NFC-enabled smartphone, if there are more individual winemakers wanted to deliver anti-counterfeiting values with NAS. It turns out that the situation will well be chaotic making the NAS not effective and efficient. Therefore, it would be better if there will be any central wine database and even a central NAS developed and built by the government or any well-known organization, like the Hong Kong Wine Merchants Chamber of Commerce (HKWMCC) promoting development on quality fine wine product, to store all the standardized wine record of those wine products imported and exported back and forth the city in the central database, and allowing all the nodes of the supply chain to update the wine pedigree along the supply chain concerning the trustworthiness, effectiveness and accuracy of all the wine records stored, the central wine database, and even those applications provided to the wine consumers or distributors for usage before transactions.

The idea of NAS should be expanded and not based for only one winemaker, but a cluster of them or a centralized NAS should be built by the government, some professional wine organizations or a strategic alliance of a cluster of wine brands, so as to better deliver the efficiency, effectiveness and anti-counterfeiting values of the NAS instead of making the wine consumers and the wine supply chain partners to download a new app every time they need to deal with another brand of wine product.

Undeniably, it is not ripe and even too early to regard the NAS the most secured anti-counterfeiting system in the world; however, the idea is that the NAS could add one more layer of security to the wine industry. It is also known to everyone that a combination of labeling technology would definitely more secured and complicated than only applying one of them to the wine industry. It is always good to say the NAS is only based on the NFC technology, which is also one of the reason why it is NFC-enabled, but the reality is that including more labeling or other anti-counterfeiting technology could make the NAS even more secured and trustworthy to the users, like adding QR code or barcode scanning functions into the ScanWINE. We should also recommend those wine brands should use the codes in addition to the NFC tag, in order to reach the greatest number of customers.
Development on NFC-enabled Wine Closure System

According to the chapter describing the Deployment of NFC tags on Wine Bottles (Chapter 6.4), the best position to place the NFC tag for the NAS would be right on the bottleneck and fully encapsulated into the packaging metal foil of the wine. However, it was proved that encapsulating an individual NFC Ferrate tag, storing tag value, into a metal foil would greatly lower the performance of the NAS, influencing both the response rate and the effectiveness of the NAS. It was then suggested that the NFC Ferrate tag should be physically intact with the packaging foil, either being part of the packaging foil to seal the wine bottle or only make contact with the foil like one depicted at the right.

We all knew that wine bottles are traditionally sealed with cork, or screw-top cap, and there are several other methods used to seal a bottle; but there is a commonality of all these sealing methods, in which all of them needed packaging foil for sealing the wine bottleneck.

As such, an idea named as NFC-enabled Wine Closure System then emerged. The idea should suit both the aforementioned sealing methods, which are screw-top cap and sealing cork. The NFC-enabled Wine Closure System is like a one-piece foil packaging with NFC printed circuit board (PCB) antenna connected. The whole packaging will be as functioned as an original NFC tag, just imagine the NFC is now transferred from circle to cylinder in shape.

The Wine Closure System is actually an overt counterfeiting deterrent if pairing with the NAS as its unique NFC-enabled seal is affixed to an individual wine bottle along with tag value stored into it, making the Wine Closure System working well with other components of the NAS, like those apps of ScanWINE and TagWINE, reading tag values and writing tag values into the Wine Closure System respectively for wine-authenticating purpose. Most importantly, the Wine Closure System will be best compatible with the NAS as it remain the NAS an openly available for the winemaker, supply chain partners and those wine consumers, as well as transferring one of the most significant anti-counterfeiting value in which the whole Wine Closure System, connected with NFC PCB antenna must be damaged before it could be uncorked to consume, making it less possible to be applied on wine counterfeits, and ensuring no more wine record with the unique would be appearing in the market and along the supply chain anymore.

Integration of Digital Marketing and Data Analytics with the NAS

Indeed, the NAS could actually further combine the anti-counterfeiting technology with brand-marketing messages, both boosting the sales performance of the wine products and the brand reputation. NAS includes an app that authenticates wine NFC labels while also enabling winemakers and other wine supply chain partners, like those wine brand promoters, to send consumers more information, via a tap of their NFC phones. After tapping the label, the tap will
direct users to a microsite of more wine information, which includes sales information, brand updates and even information on new coming wine.

Interest is growing among those advertisers of wine products in using NFC tags to both promote products and gather data on consumers, like the consumer preference or behaviors, to send more targeted advertising, like that information appeared in the microsite. For instance, through the NFC tags and the microsites, brands also collect data about which wine products consumer interact with, which pages on the microsite or the app are most viewed, and which types of wine is the most purchased one, but not geographic or identifying information about individual consumers.

It is undeniable to say that the wine consumers will only allow advertisements which add value to their preference and they are interested, such as information about the suggested cheese pairings for wine, rather than those “random Google-type adverts to make you buy a wine without any value added to throughout the selecting and purchasing processes of those wine consumers. Those wine advertisers could then send more narrowly targeted follow-up promotions to those smartphone users demonstrating the most interest in the NFC-enabled ads of some wine products, even if they do not know their names. Of course, even without the names, the tracking would require the wine consumers to opt in.

**Integration with NFC-enabled Track-and-Trace System with Advanced Features**

Instead of only carrying out wine-authenticating functions to deliver the wine anti-counterfeiting value, the NAS could also equip with track-and-trace features on wine shipments and its updates along the supply chain of the wine products, especially for those wine supply chain partners.

In fact, there is a method to add track-and-trace feature to the existing NAS, which is a way that each NFC-enabled device utilized by those supply chain partners could be assigned with a unique serial number by the winemaker which could also be registered when the partners tap the wine product before the wine acceptance is approved when using the ScanWINE, under which the location of the wine could therefore be captured by with the use of GPS of the NFC-enabled device and wrote into the wine database as an attribute, like “wineLocation” for storage, and include one more function of including the information of location to the app of ScanWINE. In this case, whenever there is a tag-reading process along the supply chain completed, there will be an update on the location of wine based on the information return from the back-end database with the GPS sent by the NFC-enabled device. This could be used to track products through the supply chain if the brand wanted to do that. The registration of serial number is not compulsory but could make the track-and-trace system even more secured as every NFC-device needed to be registered before utilization of the supply chain partners.
There are also some advanced features built based on the track-and-trace system such as the NFC temperature sensors system, under which there will be a new NFC-compatible temperature sensors that have a fifteen year battery life and can be read through wooden cases of wine introduced to the track-and-trace system. The cases of wine or simply a bottle of wine with packaging box could motivate the supply chain partners or the wine consumers to verify quality conditions, give retailers more information to share at point of sale, and lead consumers to check the quality of what they are going to buy. Similar to the track-and-trace system, some attributes should be added to the database system such as “wineTemperature” storing the parameter of the temperature whenever there is a tag-reading procedure carried out along the supply chain.

8.2 Summary and Conclusion

To sum up, the NAS project has actually achieved all the objectives, described under the “Objectives of Constructing the NAS”, in which the objectives such as understanding the background of the rampant wine-counterfeiting situation in China and even in the world, designing the overall NAS structure and communication mechanism between different components of the NAS and building solid models for components like the wine database, the ScanWINE and the TagWINE with compatible NFC-enabled smartphone and NFC tag selected. It would be fair to comment that the project has been successful as the solid model of the NAS could eventually be constructed, tested with different situations, like the situation when the NFC tags were being cloned by counterfeiters, and even demonstrated to the public for further improvements on the security consideration and the aesthetic values on the general layout of both the wine database and applications.

The NAS project has actually developed, exactly based on a standard software development life cycle named as NAS Development Life-cycle, in which the whole NAS development process was actually commenced at a stage of problem definition in which the international and Chinese wine counterfeiting situation, the limited effectiveness of existing labeling technologies were identified and noted according to those literature reviews, giving strong incentives to design and build an anti-counterfeiting system, using NFC, under which the labeling technology has never been applied for this purpose. The components like the applications and database were then designed and developed once all the requirement definition and analysis of different components were done. All the components were then connected together through designing APIs at the application development tools and programming functions included in the “AppController” of the web-based database. The prototyped NAS was then put to test so that the most suitable NFC tag working with the NAS could therefore be determined and adopted for a series of demonstrations to supervisors and potential users. It is not surprised to say that every improvement needed inputs like feedbacks or reactions from the market so did the prototyped NAS.

As such, there were surveys to collect the general feedback towards the prototyped NAS, and therefore, the prototyped NAS was then further improved based on the findings from the surveys, although both the wine consumers and wine industry players were delighted with new application of NFC on anti-counterfeiting purpose and satisfied with the outcomes delivered by
the NAS. Apart from the improvement made, there were also bunches of future works suggested to further improve the NAS after the project submission, like building the extension version of wine database and ScanWINE for supply chain partners so that they could view the shared wine records on the same platform, which will well be making the system more user-friendly and integrated.

Though the NAS has now successfully been built up and available for further industrial testing and demonstration, it is too early and even naive to say that the NFC-enabled anti-counterfeiting system would be the most secured anti-counterfeiting techniques being adopted especially in the wine industry. It is, however, right to a certain extent that the NAS is actually able to add one more layer of security to the current wine industry, under which there will be one more anti-counterfeiting system using labeling technology – NFC, could be applied on the wine bottle, specially on the bottleneck so that the NFC tag should be damaged before the wine is uncorked, and this brand-new application of NFC to the wine industry, using one’s own NFC-enabled smartphones, will in all likelihood contribute, provide a solid example and even lead to further development on anti-counterfeiting system, mainly utilizing NFC, for wine industry or even for other luxury goods industries in the nearest future.
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Appendix 1 – List of NFC-enabled Phone by 2014

The most updated list of NFC-enabled mobile phone could be viewed at: https://en.wikipedia.org/wiki/List_of_NFC-enabled_mobile_devices

Appendix 2 – NFC Forum Standard on Choosing NFC Tag

The most updated map of the NFC Standards, Products and Specifications could be viewed at: http://open-nfc.org/documents/PRE_NFC_0804-250%20NFC%20Standards.pdf
Appendix 3–Technical Specification of Hardware Tools

1. Technical Specification - Mifare Ultralight C NFC Tag

2. Technical Specification – Samsung Galaxy Note 3

3. Technical Specification – Mifare Classic 1K NFC Tag

4. Technical Specification – NTAG203 NFC Tag
The NFC Forum has created the NFC Data Exchange Format (NDEF) and the NFC Forum Type Tag Operation. NDEF is a data format to encapsulate and identify application data that is exchanged between NFC-enabled tags and devices. A type of such device is the NFC Forum Type Tag. The Type Tags are contactless tags based on currently available products capable to store NDEF formatted data and operate one of the many NFC Forum Tag Platform. Just imagine a situation when we just bought an USB, we have to format before using it so does the NFC tag, and NDEF is the format of every NFC tag, just like the customized EPC numbering scheme and memory structure of those UHF RFID C1G2 tag demonstrated by a research paper – “Implementation issues in RFID-based anti-counterfeiting systems”, the NFC tags have their own default numbering scheme set by the NDEF format.

The application data stored inside an NFC Forum Tag is encapsulated firstly into an NDEF message and secondly into the data structure specified by the NFC Forum Type Tag Platform. The NDEF message and the NFC Forum Type Tag Platform encapsulations are used to identify the type of application data stored in the NFC Forum Tag e.g. an URL, a v-Card, a JPEG image, signature or text and to guarantee the interoperability and the coexistence between applications.

NDEF is strictly a message format. It is a lightweight, binary message encapsulation format to exchange information between NFC Forum Device and another NFC Forum Device or an NFC Forum Tag. Below are some of the key specifications of NDEF - The application payloads may be of arbitrary type and size. The entire payload will be encapsulated in one NDEF message. The type identifiers may be URIs, MIME Types or NFC specific types. The length of the payload is an unsigned integer indicating the number of octets in the payload. There is an optional payload identifier field, which will help in the association of multiple payloads and cross-referencing between them. NDEF payloads may include NDEF messages or set of data chunks whose length is unknown at the time data is generated.

The design goal of NDEF is to provide an efficient and simple message format that can accommodate the following - encapsulating arbitrary documents and entities, including encrypted data, XML documents, XML fragments, image data like GIF and JPEG files, etc. Encapsulating documents and entities initially of unknown size. This capability can be used to encapsulate dynamically generated content or very large entities as a series of chunks. NFC applications can take advantage of such formats by encapsulating them in NDEF messages. For example, NDEF can be used to encapsulate an NFC-specific message and a set of attachments of standardized types referenced from that NFC-specific message. Compact encapsulation of small payloads should be accommodated without introducing unnecessary complexity to parsers.
**NDEF Message**

NFC Data Exchange Format is a lightweight binary message format. It is designed to encapsulate one or more application payloads in a single message construct. The single message construct is called NDEF Message. Each NDEF message consists of one or more NDEF Records. Each NDEF Record can carry a payload of an arbitrary type and up to $2^{31} - 1$ octets in size. If the payload is larger, then the records can be chained to support bigger data.

The first record in the NDEF Message is marked with MB (Message Begin) flag set and the last record is marked with ME (Message End) set. The minimum record length is 'one' which can be constructed by setting MB and ME in the first record. The maximum number of NDEF records that can be carried in an NDEF message is unbounded. NDEF messages must not overlap. If you want to send more than one NDEF message, then each NDEF message must be encapsulated in the form of a NDEF record. NDEF records do not carry any index. The ordering of the records is given by the way they are serialized. If an intermediate application repacks the data, then it must take care of the ordering too.

NDEF Records are variable length records with common format. Below is a NDEF Record layout –

- **MB**: It is a 1-bit field. When this flag is set, it indicates the start of NDEF Message.
- **ME**: It is a 1-bit field. When this flag is set, it indicates the end of NDEF Message.
- **CF**: It is a 1-bit field. It indicates whether the record is either the first record chunk or a middle record chunk of a chunked payload.

An NDEF message can contain zero or more chunked payloads. A record chunk carries a chunk of payload. Chunked payloads can be used to partition dynamically generated content or very large entities into multiple subsequent record chunks serialized within the same NDEF message. In each chunked payload is encoded as an initial chunk followed by zero or more middle chunks and finally by terminating chunk. Each record chunk is encoded as an NDEF record using the following guidelines - The initial record chunk is an NDEF record with the CF (Chunk Flag) flag set. The type of the entire chunked payload MUST be indicated in the TYPE field regardless of whether the PAYLOAD_LENGTH field value is zero or not. The PAYLOAD_LENGTH field of this initial record indicates the size of the data carried in the PAYLOAD field of this record only, not the entire payload size. The ID field MAY be used to carry an identifier of the entire chunked payload.

Each middle record chunk is an NDEF record with the CF flag set indicating that this record chunk contains the next chunk of data of the same type and with the same identifier as the initial record chunk. The value of the TYPE_LENGTH and the IL fields MUST be zero and the TNF (Type Name Format) field value MUST be 0x06 (Unchanged). The PAYLOAD_LENGTH field indicates the size of the data carried in the PAYLOAD field of this single middle record only. The terminating record chunk is an NDEF record with the CF flag cleared, indicating that this record chunk contains the last chunk of data of the same type and with
the same identifier as the initial record chunk. The value of the TYPE_LENGTH and the IL fields MUST be zero and the TNF (Type Name Format) field value MUST be 0x06 (Unchanged). The PAYLOAD_LENGTH field indicates the size of the data carried in the PAYLOAD field of this single terminating record only.

- **SR**: It is a 1-bit field. If this flag is set, then the PAYLOAD_LENGTH field is a single octet. The short record layout is intended to compact encapsulation of small payloads, which will fit within PAYLOAD fields of size ranging between 0 and 255.

- In the above layout SR = 1. The PAYLOAD_LENGTH filed is of only 1 octet. The max value is $2^8 - 1$.

- **IL**: It is a 1-bit field. If this field is set, then the ID_LENGTH field is present in the header as a single octet. If the IL flag is zero, the ID_LENGTH field is omitted from the record header and the ID field is also omitted from the record.

- **TNF**: This is a 3-bit value. It indicates the structure of the value of TYPE field.

- **TYPE_LENGTH**: The TYPE_LENGTH field is an unsigned 8-bit integer that specifies the length in octets of the TYPE field.

- **ID_LENGTH**: The ID_LENGTH field is an unsigned 8-bit integer that specifies the length in octets of the ID field. This field is present only if the IL flag is set to 1 in the record header. An ID_LENGTH of zero octets is allowed and, in such cases, the ID field is omitted from the NDEF record.

- **PAYLOAD_LENGTH**: The PAYLOAD_LENGTH field is an unsigned integer that specifies the length in octets of the PAYLOAD field (the application payload). If the SR flag is set, the PAYLOAD_LENGTH field is a single octet representing an 8-bit unsigned integer. The max size will be $2^8 - 1$ octets. If the SR flag is clear, the PAYLOAD_LENGTH field is four octets representing a 32-bit unsigned integer. The max size will be $2^{32} - 1$ octets.

- **TYPE**: The value of the TYPE field is an identifier describing the type of the payload. The value of the TYPE field MUST follow the structure, encoding, and format implied by the value of the TNF field as described in TNF section above.

- **PAYLOAD**: The PAYLOAD field carries the payload intended for the NDEF user application. Any internal structure of the data carried within the PAYLOAD field is opaque to NDEF.
Appendix 5 – Sitemap Diagram of the Web-based Wine Database
Appendix 6 – Entity and Attribute Diagram of the Wine Database
Appendix 7 - Entities Relationship Diagram of the Wine Database
Appendix 8: The Database Structure Design

For the Identity Entities Diagram, it was defined into three parts, which were Collection (Red), Entity (Yellow) and Attribute (Blue) respectively. The lists of Active wine, Inactive wine, Project and the supply chain partners were put under the layer of “Collection” meaning the whole data will be stored and appeared in the database, and there are associated functions, also called as events, like the User Login, Edition/Creation of all the records of wine, project and supply chain partners, as well as some other basic functions such as sorting, searching and sharing were also put under the layer of “Entity”, so that the database of NAS with the aforementioned functions could better increase the efficiency on data operation and management, and the interaction between different entities. In fact, there are FIVE basic entities shown in this Identity Entities Diagram, which are the "User Account", "Active Wine", "Inactive Wine", "Projects" and "Partners".

Regarding to the layer of “Entity” and “Attribute”, the “has a” relationships were shown appropriately based on the inclusive relationship between different items in those layers, like each Active Wine and its association will “have a” Wine Detail, the project and its associations such as creation and edition will “have a” project detail, so far and so on, indicating that each entity “has a” attribute to operate. For the details of attributes each entity stored, for instance, the wine detail has a lot of necessary attribute, such as wine title, wine status, last transaction date, the transaction record, so that the wine record is indicative and informational to perform those functions and even convey the anti-counterfeiting values of the whole NAS.

Furthermore, there are also some important attributes set for different purposes of the NAS; for instance, the “WineStatusID” is the wine status to control where the wine record will be still under the tab of Active Wine or being transferred to the tab of Inactive Wine for denoting it as a suspicious wine found along the supply chain when there is nothing returned while the app made request to assess the back-end database, or a sold wine when the status and the transaction record are updated while the payment is confirmed. The are also some noted attributes such as the “RejectionID” in which it relates to the reason of rejection while there is wine being rejected by the supply chain partner, and the “TrustStatusID” in which it refer to the Trust Status of a supply chain partner which will also be updated when pre-registration is so confirmed from that partner. All the attributes of the specific entities are shown in the Identity Entities Diagram.

For the Entities Relationship Diagram, there are totally 11 entities, for those additional six sub-entities, which are from the result of normalization. Normalization can make the data model more flexible and reliable; however, it does generate some overhead because it usually require to get more tables, but it enables to do many things with the data model without having to adjust it. To achieve normalization, the database should confine with the following 2 properties, which are no repeating elements or groups of the elements and all foreign keys attributes fully functionally dependent on the whole primary key. For instance, there are repeating elements such as wine category and wine status; therefore, there are two more additional sub-entity tables called “WineCategory” and “WineStatus” built with the WineCategoryID and WineStatusID to link back to the original entity table of “Active Wine” so as to prevent the repeating the element, leading to low efficiency of data response and bulkiness of the general database.

As aforementioned, there are FIVE basic entities tables, which are “User Account”, “Active Wine”, “Inactive Wine”, “Projects” and “Partner Information”. Each of them stores the necessary attributes with appropriate data type for the purpose of the entity table; for example, the attribute of “TransactionRecord”
is needed to store those status record of the wine either manually input by the winemaker, like status of production, bottling and even the NFC writing processes, or atomically updated based on the NFC scanning activities throughout the supply chain of the wine.

To enable the entity relationship, the relationship of primary key and foreign key should be set so that a relative entity tables could be linked together in which there will be a primary key assigned for each entity table. There are 11 primary keys (denoted as “PK”) and 17 foreign keys (denoted as “FK”) enabling 19 relationships throughout the whole information structure of the database.

Indeed, according to the Entity Relationship Diagram in the above, there are different categories of relationship. For the entity table of “Project”, there could be more than one project status with data type of “varchar(10)” stored in the entity of “Project Status”, and there would be more than one project status able to be chosen by the winemaker when create or edit a project record. A one-to-many relationship would be set between the entity tables of Project and Project Status, in which the relationship with each instance of Project Status is related to a minimum of zero and a maximum of many instances of Project is set, as the entry of key - “ProjectStatusID” could be “Null” in which the columns of input of this data will not be compulsory and could be with no data at all under which the minimum of zero instance could be possible between this relationship. According to the same methodology, the similar relationships are set between the entity tables of “Active Wine” with that of “WineCategory” and “WineStatus”, between entity tables of “Partner Information” with tables of “Group” and “Trust Status”, and between the tables of “Unauthorized Transaction” with that of “Rejection”. This kind of relationship could be visualized whenever there will be a dropdown list for “Wine Status” to choose the desired status during the process of creating a new wine record at the web-based database.

While for the entity table of “User Account”, another kind of one-to-many relationship is being constructed, between that entity table with other relating tables such as table of “Active Wine”, table of “Unauthorized Transaction” and “Partner Information”. However, the one-to-many relationship is different from that shown above, under which for this case each instance of those tables connected with the table of “UserAccount” will be related to a minimum of one and a maximum of many instance of the table of “UserAccount”.
Appendix 9: The Adoption of PhoneGap Framework

PhoneGap (Cordova) is an open-source mobile development framework for quickly building cross-platform mobile apps using HTML5, JavaScript and CSS, instead of being bounded by those device-specific languages, such as Java, in which, normally, different operating systems will need different languages and platforms to build mobile apps. For instance, Android and BlackBerry require Java, while the iOS requires Objective-C as the primary programming language. With the advent of PhoneGap, all the functions could be designed and built using JavaScript, which is way easier than using mainly JAVA and the Bootstrap CSS could be adopted.

The PhoneGap solves this by using standards-based web technologies to bridge web applications and mobile devices, making PhoneGap app is cross-platform in nature. PhoneGap is indeed a set of device APIs that allow a mobile app developer to access native device function such as the camera or accelerometer from JavaScript. Combined with a UI framework such as jQuery Mobile or Dojo Mobile or Sencha Touch, this allows a smartphone app to be developed with just HTML, CSS, and JavaScript. When using the Cordova APIs, an app can be built without any native code (Java, Objective-C, etc) from the app developer. Instead, web technologies are used, and they are hosted in the app itself locally. And because these JavaScript APIs are consistent across multiple device platforms and built on web standards, the app should be portable to other device platforms with minimal to no changes.