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On the Security of Internet Banking in South Korea

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Abstract

South Korean Internet banking systems have their own unique way of enforcing security controls. Users are *obliged* to install security software to access the Internet banking services. Typically, this takes the form of an ActiveX plugin that implements a proprietary security mechanism on the users' platform. The banks and the software companies claim that this approach provides trusted user platforms and will eventually lead to secure Internet banking.

In this paper, we identify inadequacies of these proprietary mechanisms and show why trusted platforms can not be achieved using them. Based on the results of a usability survey, we argue that these mechanisms are being distributed at the cost of usability penalties without offering much improvement to overall security. We also recommend several enhancement strategies based on social engineering and trustworthy computing techniques.

1 Introduction

The Internet has changed the way people use banking services. In South Korea, Internet banking has become very popular [1]. The banks have actively promoted online services to save costs and create new business opportunities. Customers benefit from carrying out financial transactions such as funds transfers and bill payments without having to go to a bank branch. The Bank of Korea reported that 57.29 million online accounts had been registered as of September 2009 [1]. This report also showed that the number of Internet banking transactions per day, on average, is 29.03 million and the amount of money being transferred is 30.17 trillion Korean Won.[1]

One curious fact, though, is that all Internet banking systems in Korea only support Microsoft Internet Explorer (and only the Windows version). Bank customers cannot use other web browsers like Safari, Firefox, Opera and Chrome. In consequence, Internet Explorer has become the dominant web browser in Korea. Recent market share trends for web browsers in different parts of the world [2] illustrate the near-monopoly of Internet Explorer in Korea (see Figure 1).

The reason is simple enough. In order to use Korean Internet banking services, the users are required to install external security plugins. As Internet Explorer is the dominant browser, the developers implemented these plugins as ActiveX controls [3], effectively locking the users in to Internet Explorer. To illustrate the ActiveX dependency of Korean web sites, we analyse the relative traffic around the keyword "ActiveX" using Google trends[2] (see Figure 2). This figure shows the relative traffic of top 10 countries around "ActiveX" from 2008 to 2009.

These plugins, however, are not included in the (de facto) web standards developed by the World Wide Web Consortium (W3C)[3], and have severe compatibility and usability issues.

The majority of the Internet banking systems are developed by three Korean software companies: SOFTFORUM[4], INITECH[5] and Ahnlab[6]. Until recently, these companies developed

[1] about USD 26 billion
[2] `http://www.google.com/trends/`
[3] `http://www.w3.org/`
[4] `http://www.softforum.com/`
[5] `http://www.initech.com/`
[6] `http://global.ahnlab.com/`

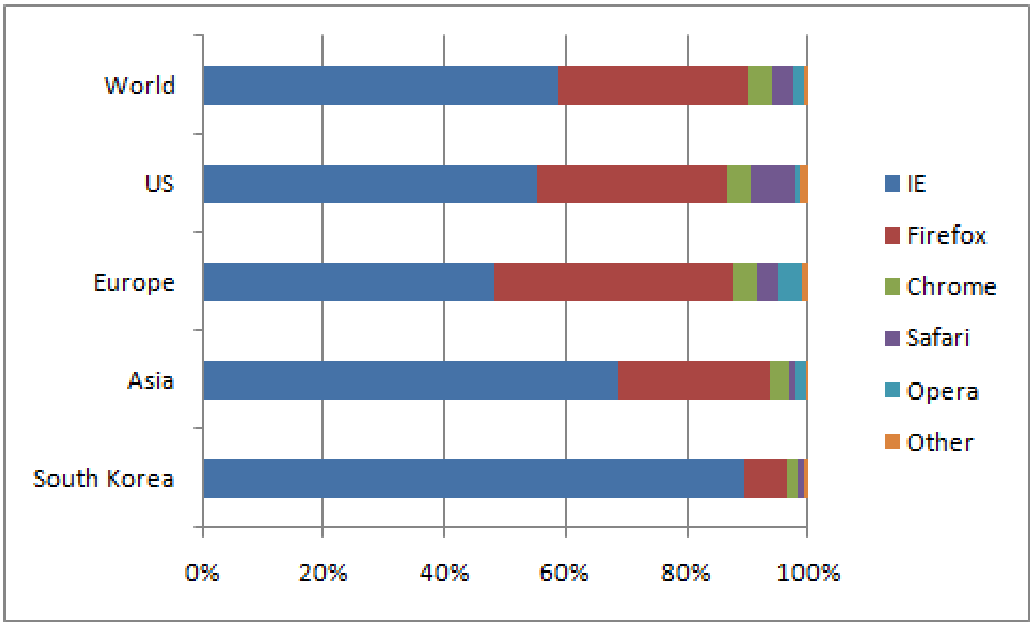

Figure 1: Web Browser Market Share by Geographic Regions (October 2009)

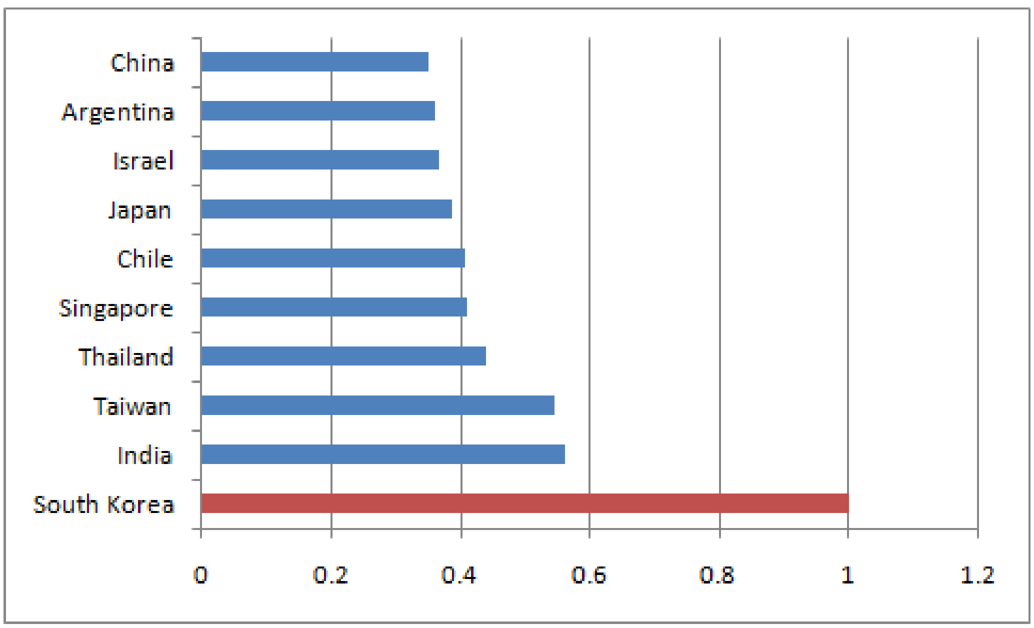

Figure 2: The Relative Traffic of Top 10 Countries Around "ActiveX" From 2008 to 2009

systems that are only compatible with Windows[7].

Much debate [4, 5] has raged around the requirement that users install external security plugins, the lack of effort by the vendor companies to provide better compatibility with other operating systems and browsers, and the usability implications for bank customers. In 2007, a non-profit organization called "OpenWeb"[8] sued the Korea Financial Telecommunications and Clearings Institute (KFTC)[9] (a Korean government agency) for 415 million Korean Won for its implicit and anti-competitive endorsement of Microsoft products. They lost the case in 2009; we believe one of the main reasons for their loss was the lack of security and usability evaluation for current Internet banking systems.

This paper aims to contribute: (1) an analysis of the strengths and weaknesses of the proprietary security mechanisms used in the Korean banking systems over the standard technologies, (2) a study of the usability issues raised from employing these proprietary mechanisms, and (3) recommendations for improving overall security as well as usability.

This paper is structured as follows. In Section 2 we describe how security is implemented and distributed in current Korean Internet banking systems. We evaluate these security mechanisms in Section 3 and discuss the usability implications in Section 4. We then recommend several enhancement strategies in Section 5. Finally, in Section 6 we discuss remaining work and conclude.

2 Security Mechanisms Used in South Korea

There are four generally accepted security properties [6] that one may require when establishing a secure channel between the user and the bank:

- *confidentiality* – only the authorized entities (i.e. the user and the bank) should have access to the content of the messages being exchanged.
- *user/server authentication* – before sending sensitive information over the Internet, the user should be assured that they are communicating with the right bank; the bank should also be able to verify the identity of the user before processing the requested transactions.
- *data integrity* – the user and the bank should be able to detect any manipulation (including insertion, deletion and substitution) or replay of data by unauthorized parties.
- *non-repudiation* – neither the user nor the bank should be able to deny previous commitments or actions; for instance, in case of disputes, the bank should be able to prove to a third party that the user has performed certain transactions.

In Korea, there are additional requirements for the provision of *trusted platforms*. A trusted platform should detect and remove all malware, and prevent malware from reading the users' private banking information. We further define this term in Section 5.3.

Table 1 summarizes the security mechanisms being used in the Korean banking systems to fulfil these requirements. We also list the mechanisms that are commonly used in the UK for comparison.

In most other countries, Secure Sockets Layer/Transport Layer Security (SSL/TLS) [7] is the de facto Internet banking standard for ensuring confidentiality and data integrity. The Korean banking systems, however, use proprietary protocols based on RSA, HMAC, and SEED (see

[7] "Shinhan Bank" and "Korea Exchange Bank" now support Mac OS X through proprietary applications.
[8] http://openweb.or.kr/
[9] http://www.kftc.or.kr/html/english/index.html

Table 1: Required Security Mechanisms in Korea and the UK

Requirements	Korea	The UK
server authentication	proprietary protocols	SSL/TLS
user authentication	ID/password OTP digital signature	ID/password OTP –
data integrity	proprietary protocols	SSL/TLS
non-repudiation	digital signature	–
confidentiality	proprietary protocols	SSL/TLS
malware detection	anti-virus	–
network access control	firewall	–
anti-keylogger	keystroke encryption	–

Section 2.1). Some combination of ID, password, one-time passwords (OTPs) are commonly used for authentication [8]. Again, the Korean systems are unique in that they also use RSA to provide extra assurance. In fact, RSA is also used for non-repudiation, a property that is rarely enforced in other countries [9].

Looking at this table, it seems that the Korean banking systems provide much stronger security than those in the UK. However, these extra security mechanisms are enabled through installation of ActiveX plugins which the users are obliged to install. The rest of the paper studies these mechanisms in detail, and explains why these mechanisms – despite the hassle they impose on users – do not add much security.

2.1 Secure and Authenticated Communication Channel

In 1999, the Korean government launched an Internet banking system based on a Public Key Infrastructure (PKI). This was adopted rapidly by the banks; by the end of 2000, 20 of them were offering Internet banking services based on this PKI [10].

A user obtains a digital certificate through a licensed Certificate Authority (e.g. the Korea Information Security Agency (KISA)[10]) if they pass an online authentication test. The process is managed through proprietary software downloaded from a bank's website. The issued certificate is stored either on the user's hard disk (e.g. `C:\Program Files\NPKI`) or in an external device such as a USB stick. Every transaction is authorized by validating the user's certificate with the CA's public key.

A secure authenticated channel (SAC) is established between the user and the bank server by exchanging the digital certificates. The protocol used to generate session keys is not open to the public. We speculate that the protocols include a digital signature mechanism that may be inspired by Secure Electronic Transaction (SET) [11], and an SSL variant using SEED [12] (see Appendix A for details). SEED is a 128-bit symmetric key block cipher developed by the KISA in 1998, with a 16-round Feistel structure. It was approved as a standard block cipher by the Internet Engineering Task Force (IETF) [12] and an ISO/IEC international standard. Since SEED and the necessary handshaking steps are not supported by mainstream web browsers – including Internet Explorer, Safari, Firefox, Opera and Chrome – an external plugin is required to run these protocols (see Figure 3).

[10] `http://www.kisa.or.kr/maine.jsp/`

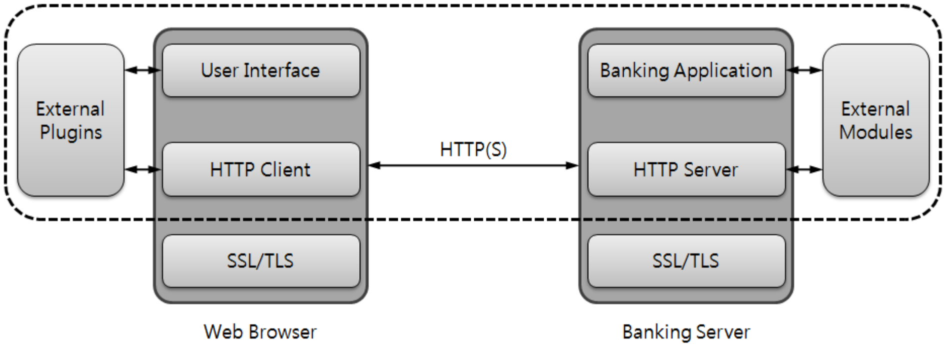

Figure 3: The SAC Enabled Through External Plugins

It may seem strange to use plugins when SSL/TLS is already available and supported by mainstream web browsers. This is in fact a by-product of the "Crypto wars" in the 1990s during which the US government tried to restrict the external availability of strong cryptography.

When Internet banking systems were first being deployed in Korea, the encryption algorithms supported by the web browsers distributed outside the US appeared to be inadequate. This is because the US government had limited the key sizes to 40 or 56 bits for symmetric encryption algorithms (RC4/DES).[11] Thus the Korean government funded the development of a new block cipher, SEED, as the country's proprietary standard for secure e-commerce. Ever since, SEED has been deployed as the de facto standard for the Internet banking systems, responsible for encrypting the sensitive financial transactions.

2.2 User Authentication

We now look at how the users are authenticated by the bank servers. A wide range of technologies are currently available and used for authentication. These include the use of passwords, Personal Identification Numbers (PINs), digital certificates (PKI), physical tokens such as smart cards, One-Time Password (OTP) generators, transaction profile scripts, and biometric identification [8].

Korean systems use some combination of two or three of these techniques, based on the belief that this approach offers stronger security than relying on just one method. A commonly deployed authentication process is described as follows:

1. A customer firstly logs into the website using their user ID and password.

2. To carry out a banking transaction, few digits from an indexed Transaction Authentication Number (iTAN) [14] stated in the user's private security card or an OTP (generated by an OTP generator) are entered.

3. Online transaction records are digitally signed with the user's secret key stored in the user's PC or external memory.

Step 2 may involve the use of an "out-of-band" channel to deliver the physical tokens, requiring extra actions beyond the technological boundaries to be performed. Some examples

[11] Blaze and others had already argued convincingly in 1996 that products using 40- or 56-bit ciphers did not give sufficient security for business applications [13].

are callback (voice) verification, e-mail approval or notification, and mobile phone based challenge/response processes.

A combined authentication mechanism, if carefully designed and implemented, should provide strong security. The use of digital certificates, for instance, seems reliable in theory. Without strong protection for the user's private keys, however, digital certificates only offer a modest solution. An attacker might try to perform privilege-escalation or in-memory attacks to read the user's private keys from the hard disk or the main memory. To mitigate these attacks, password-based encryption for the private keys has been legislated: an encryption key, derived from the customer's password alone, is used to protect the private keys. The KISA proposed a specification in 2004 – derived from the Public Key Cryptography Standard (PKCS) #5 [15] – where "SEED" is the standard encryption algorithm used. Triple DES was added as another standard encryption algorithm in 2007.

2.3 Trusted User Platforms

The user is the ultimate "client" of the system and not the web browser. The user connects to the bank server through the interfaces available on the web browser, just as an automated teller machine also provides a terminal for the user. The browser collects the user input, makes requests to the bank server to perform certain transactions, receives the server response/data, and displays the output to the user. A trusted user platform, therefore, is required to secure this communication channel (see Figure 4) between the user and the browser.

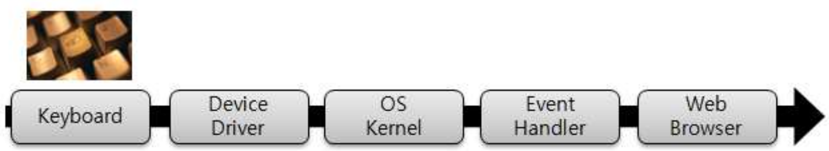

Figure 4: The Communication Channel Between the User and the Browser

In reality, this communication channel is attacked by malware that tries to read the user's sensitive information (such as user credentials and credit card details). Essentially, the attackers use social engineering tricks to sidestep the cryptography. Malware has been distributed as email attachments, or as software downloaded (intentionally or unintentionally) from the Internet. For example, websites ask users to download a special codec, which is actually malware designed to steal sensitive information [16].

To mitigate such attacks, the Korean banks oblige users to install further security plugins – which are automatically installed and executed when the users first access the banking service:

- An anti-virus software is installed to provide real-time protection against known malware. In general, it detects malware by going through the files on the customer's disk and removing all the files that match the signatures in a blacklist. Therefore, it relies on timely updates and on the integrity of the blacklist. The Korean banks require the blacklist to be updated in real time.
- A personal firewall is designed to prevent the malware communicating with an external adversary. It monitors all incoming and outgoing traffic and permits only authorized connections.
- A keystroke encryption routine encrypts sensitive information from the moment it is typed into the keyboard until it reaches the browser (see Figure 4). This is intended to prevent the information from being read or tampered with en route to the browser.

3 Why are These Security Mechanisms Not So Effective?

At first glance, the Korean Internet banking systems seem more secure than the systems used in Britain (see Table 1), or in other countries. Certainly more security mechanisms have been sold to the banks and are distributed by them. In this section, we identify the fundamental problems with these mechanisms and show why they only offer a modest improvement.

3.1 No Protection Against Phishing Attacks

Phishing attacks involve masquerading as a bank and deceiving the users into disclosing their account details [17]. The users may be asked to update or re-enter their confidential information through fake web pages. These attacks have become sophisticated over the years, making it difficult for users to identify fake websites.

To avoid phishing attacks, users need to check whether the email sender or website owner is a trusted entity. Server authentication at the protocol-level is not sufficient. The client software, installed on the user's machine, cannot decide whether the website represents the trusted entity the user originally intended to communicate with.

One possible approach is to deliver the server verification results to the users visually. Modern web browsers already provide security indicators or warning messages based on blacklists and extended-validation SSL certificates, identifying fake sites and presenting risk information visually. However, this feature cannot be used by Korean customers since SSL/TLS is not part of the Korean system. For the time being, the best one might do is to try to educate users about these attacks and the associated risks – but that has been found in Europe and the USA to not work very well; in general "blame and train" is not a good way to fix usability problems. It is much preferable to make the system more usable.

3.2 Problems with Digital Certificates

In theory, digital certificates provide a neat solution for user authentication. In practice, however, PKI has proved to be difficult to deploy due to the difficulty of protecting the private keys and the high maintenance costs [18]. In Korea, there seems to be a common misbelief that PKI is already well established for e-commerce and provides high assurance for user authentication.

The protection of the private keys is critical part of PKI. An adversary, by stealing a private key, can impersonate a genuine customer and perform transactions online. Therefore, the private keys should always be protected using secure disk storage and memory mechanisms [8].

Korean banking systems store password-encrypted files of private key material on the user's hard disk. There are two problems with this approach: (1) a successful privilege-escalation attack would allow an adversary to read the encrypted file, or the decrypted key stored in memory; and (2) the security is only as good as the password. Malware can steal the user's password through brute-force attacks or key logging.

As discussed in Section 2.2, Korean banking systems require a combination of passwords, OTPs, and digital certificates for authentication. We argue that digital certificates are redundant here because the private keys are only protected with the passwords; by compromising the passwords, adversaries also get the private keys. In fact, this is the main reason why the OTPs were introduced in the first place – to limit the exposure to keyloggers. A well-implemented iTAN system (as seen in Germany) compels the attacker to use session stealing or a man-in-the-browser attack.

If the private keys could be strongly protected, however, PKI alone should be sufficient for authentication. In Section 5.3, we discuss how this could be achieved through the use of trustworthy computing capabilities [19].

3.3 Limitations of the External Plugins

In Section 2.3, we discussed how the customers are obliged to install four external plugins – in addition to the protocol crypto plugin, there's an AV product, a firewall, and keystroke encryption software – to use Internet banking. We identify the inadequacies of these plugins and argue that trusted user platforms cannot be achieved through this approach.

An anti-virus product typically uses wither signature-based detection or heuristics-based detection. The problem with the former method is that new malware or variants cannot be detected efficiently. The latter is based on heuristics such as monitoring registry changes and the insertion of hooks into certain libraries or system interfaces. Since these heuristics are not based on any fundamental characteristics of malware, they often incur high false positives and false negatives [20].[12]

The firewall software shipped by Korean banks runs only while the user is using the Internet banking service. So malware, that wants to bypass it can just wait until the user logs off to send sensitive information over to external adversaries. The product may provide some protection against session stealing and man-in-the-browser attacks [22] but seems rather limited. Perhaps this is necessary; if it interfered with the user's online activities when she was not engaged in banking, it could be unacceptable.

The keystroke encryption software has limitations too. First, it cannot prevent the key scan codes from being intercepted by interrupt hooking methods; encryption only happens afterwards. Second, successful privilege-escalation attacks or buffer overflow attacks would allow malware to modify or simply delete this software. Third, if not designed carefully, this software could prevent normal key inputs from being read by the installed, benign programs. Fourth, it cannot prevent hardware keyloggers in situations where the user accesses the banking services through a public machine. Finally, the encryption keys themselves could be compromised. Without strong protection for the encryption keys (e.g. through a hardware mechanism such as the TPM [19]) and verification of the code responsible for managing these keys, keystroke encryption methods only offer slight improvement.

These external plugins may be effective against simple, naive malware. As soon as a malware becomes sophisticated enough to perform various privilege-escalation, in-memory, and brute-force attacks, these external plugins become less effective. This raises a question of how much they add. Engineers should consider the balance between widely-deployed protection mechanisms (such as those in the operating system), the benefits of user education (limited as they are), and what should be provided using proprietary mechanisms. (In Section 5.1, we further discuss the social engineering aspects.)

3.4 Lack of Security Proof

Korean Internet banking systems use proprietary authentication protocols. Some may argue that closed protocols will help prevent a number of known attacks; others argue that open protocols can become more secure than the closed ones through ongoing verification and patching efforts. Making the specifications available to the public could help both developers and attackers. Closed information on the other hand can slow down the attackers initially, but, attackers eventually find and exploit vulnerabilities. Where does the balance lie?

We believe that prevention is better than cure. Protocols are not like operating systems, which will inevitably have many bugs; protocols are compact things, which are hard to design properly, and which commonly contain one or two bugs initially that get found once many people (including academics) study them. Protocol security should therefore be thoroughly analyzed by experts for a period before any protocol is seriously deployed. We are therefore concerned

[12] Cohen [21] demonstrated that there is no algorithm that can detect all possible viruses.

about the proprietary protocols used in the Korean systems. We have no idea what verification might have been done on them. Are there any formal proofs of correctness? If there were, then surely KISA can have no objection to publishing both the protocols and the proofs. SSL/TLS on the other hand has been studied for a long time, and formally verified [23] – its end-to-end security is equivalent to the cryptographic strength of the underlying algorithms if implemented properly [24]. The security offered by SSL/TLS has been the subject of comprehensive analysis [25, 26, 23, 27, 28, 29]. If and when flaws are found, they are generally addressed quickly by the community. Because SSL/TLS has a security proof and none has been supplied for the Korean protocols, we believe that the former must be assumed to provide better security.

Arguments against the use of SSL/TLS due to published implementation vulnerabilities are unreasonable [30, 31, 32, 33, 34]. At least the basic protocol is sound; and attacks using timing channels, poor random number generators etc are at least as likely to affect proprietary protocols – if not more so, as the common implementations of SSL/TLS are open-source and widely studied.

4 What the Users Think About the South Korean Services

To investigate the usability implications of employing the security mechanisms discussed here, we conducted an anonymous online survey (see Table 2) to study (1) how users feel about using Korean services compared to those from other countries; and (2) why users prefer, or do not prefer, using Korean services over services from other countries. We made the assumption that services from other countries do not require their users to install extra security software (which is generally the case).

We invited our friends and colleagues as well as several online communities in Korea to participate, and got a total of 401 participants. 80 of these participants had experiences of using banking services from Korea as well as from other countries (see Q2), out of a total of 379 people who had experience of Korean services (see Q1). The participants' IP addresses were checked to prevent multiple responses.

The results for Q3 show that 70% of those who have had experiences in using both services prefer to use the services from other countries. Q5 reveals that the two most common reasons for this is due to their simplicity and better compatibility with web standards. The results for Q8 and Q9 indicate that 68.9% of those who have used Korean services felt uncomfortable, mainly due to their complexity and lack of compatibility with web standards.

For Q4, Q5, and Q9, some participants offered other interesting reasons. In particular, for Q9, 25 participants commented about the system crashes that result from installing the ActiveX plugins. 4 participants commented about the inconvenience of having to carry around digital certificates to use the Internet banking services.

It must be said, though, that none of the users were impressed with the security of other countries' banks (Q5) while 58.3% said that the most important reason they prefer Korean services was "It feels more secure" (Q4). We argue in this paper that Korean services are not actually more secure, but perhaps unsophisticated users assume that services which are complex and difficult to use must also be complex and difficult to defraud. Perhaps this is another example of "security theatre", which tackles the feeling but not the reality.

5 Our Recommendations

Having identified the major usability and other problems of the proprietary security mechanisms, we now recommend a number of enhancement strategies to improve the overall security and usability of the Internet banking systems in Korea.

Table 2: Usability Survey Results

Q1. Do you have experience in using a Korean Internet banking service?	
Yes	94.5% (379)
No	5.5% (22)
Q2. Do you have experience using an Internet banking service from another country?	
Yes	21.1% (80)
No	78.9% (299)
Q3. If you had to select one service for Internet banking, which country's service would you prefer to use? (For those who have answered "Yes" to Q2)	
Internet banking service from Korea	30.0% (24)
Internet banking service from another country	70.0% (56)
Q4. What is the most important reason you prefer the Korean service?	
It's simpler	25.0% (6)
It's faster	8.3% (2)
It's more compatible with the Web standards	0.0% (0)
It feels more secure	58.3% (14)
Other	8.3% (2)
Q5. What is the most important reason you prefer the service from another country?	
It's simpler	50.0% (28)
It's faster	1.8% (1)
It's more compatible with the web standards	39.3% (22)
It feels more secure	0.0% (0)
Other	8.9% (5)
Q6. If all of the services provide the same level of security, which country's service would you prefer to use? (For those who have answered "Yes" to Q2)	
Internet banking service from Korea	15.0% (12)
Internet banking service from another country	63.8% (51)
I don't mind using either	21.3% (17)
Q7. Do you know why ActiveX controls are installed on your machine when you use the Korean banking service? (For those who have answered "Yes" to Q1)	
I know exactly	32.2% (122)
I know briefly	49.1% (186)
I have no idea	18.7% (71)
Q8. How often have you felt uncomfortable using the Korean banking service?	
All the time	41.7% (158)
Most of the time	26.9% (102)
Sometimes	27.2% (103)
Never	4.2% (16)
Q9. Why did you feel uncomfortable using the Korean banking service?	
It was complicated	20.9% (76)
It was slow	11.6% (42)
It had compatibility issues with the web standards	45.5% (165)
It felt insecure	7.7% (28)
Other	14.3% (52)

5.1 Providing Options to the Users

Users are obliged to install a number of security (ActiveX) plugins while using online banking services. As a result, the users have no option but to use Internet Explorer and Windows to perform online banking transactions. Our survey shows that the majority of the users find Korean services uncomfortable to use, due to various compatibility and usability issues (see Section 4). We have also demonstrated that most of these plugins only offer a modest improvement, mainly because these are designed to run on top of insecure operating systems and kernels (see Section 3.3). A successful privilege-escalation attack, for example, would be sufficient to turn them off or steal private keys.

Even if these plugins somehow guarantee a significant improvement, it still seems unreasonable to oblige the users to install them without providing comprehensible information about the assumed threats and claimed benefits. Our survey indicates that many users have installed these plugins without exactly knowing what the benefits might be.

A more user-friendly system should only recommend security plugins and allow the users to decide whether or not to install them. In fact, some banks in other countries already allow their users a choice. For example, the Royal Bank of Scotland's "staying safe online" webpage [35] informs their users about a security product that can be downloaded and gives an overview of the threats, benefits, and system requirements. Likewise, the benefits and risks should be clearly explained in terms that normal users can easily understand. This would allow the users who wish to use different web browsers or operating systems to make informed choices.

5.2 Adapting More User-Friendly, Compatible Mechanisms

Another method for improving the overall usability and compatibility is to replace the proprietary mechanisms with more user-friendly, compatible mechanisms. Since the proprietary security mechanisms, enabled through the ActiveX plugins, have serious weaknesses in the way they are designed or used (see Section 3.3), we believe the overall security should not be affected much (and could even improve) by replacing them with the following mechanisms.

In Section 3.4 we discussed why switching to SSL/TLS is likely to be safer than proprietary protocols (it has a security proof, after all). This would not only reduce the number of external components required but allow users to choose essentially any modern browser. In addition, this would allow the use of industry-standard mechanisms for mitigating phishing attacks such as extended-validation certificates and collaboratively-generated blacklists.

For digital certificate based user authentication, we recommend using SSL/TLS client certificated with standard cryptographic token interfaces. Netscape-based browsers already support PKCS #11 [36], and Internet Explorer supports Microsoft's Cryptographic Application Programming Interface (CAPI) [37]. These standard APIs are well defined and allow different implementations of cryptographic plugins to work with each other. Adapting this technique would allow the banks and the users to have more flexibility in choosing the cryptographic component suitable for their operating environment: this component is called Cryptographic Service Provider (CSP) in CAPI and cryptoki in PKCS #11.

The firewall plugin does not add much to security since it only runs during an online banking session, and is switched off as soon as the user logs off. The banks should think about whether session-stealing and man-in-the-browser attacks are real issues in Korea; if not, this component could be dispensed with.

5.3 More Trustworthy Computing Approaches

Adding extra security components on top of an insecure operating system or kernel will not result in a trusted user platform. If the threats discussed in Section 2.3 become critical in

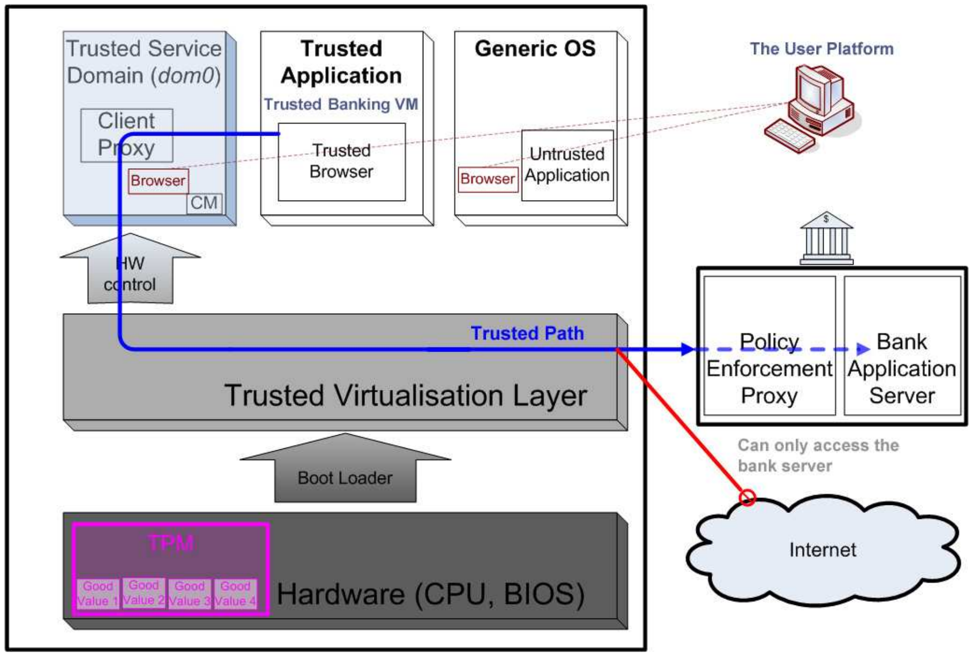

Figure 5: OpenTC's Secure Banking Prototype (Adapted from [40])

the future, and the provision of trusted platforms becomes necessary, a more complete security solution should be deployed instead. What are the options?

By a complete solution, we refer to an online banking system that (1) runs on top of a trustworthy, integrity protected kernel and security components, (2) is strongly isolated from the rest of the system, (3) has its private keys protected by both software and hardware, (4) allows a remote server to verify the integrity of these security properties, and (5) communicates with the bank server through a trusted path. We examine existing technologies and approaches that may be adapted in the future to ensure these properties and enable a trustable, verifiable user platform.

The isolation requirement might at first sight be amenable to protections based upon operating-system level techniques like sandboxing. After a few moments' thought on the number of lines of code contained in mainstream operating systems and their known vulnerabilities [38], however, it is evident that no strong isolation can be achieved in this manner. Virtualization [39] on the other hand is capable of providing a much stronger isolation through the relatively smaller virtual machine monitor and privileged virtual machine.

The Open Trusted Computing (OpenTC) consortium has implemented a "Secure Banking" prototype [40] based on Xen virtual machine monitor [39] (see Figure 5). Their prototype serves to demonstrate how virtualization and trusted computing could be used to prepare a trusted (TPM-measured) banking virtual machine, verify its state, and access the bank server through the trusted virtual machine. Trusted computing attestation [19] ensures that only a fully isolated, integrity-protected banking virtual machine can access the bank server to perform online transactions. The banking virtual machine is also capable of verifying the authenticity and integrity of the bank server. As a result, a trusted path is established from the user to the bank server. Using this virtual machine, the user can only ever reach the bank server – this would be sufficient to prevent phishing attacks. Any private key used is sealed (encrypted) to the trusted computing base, preventing other untrusted virtual machines or a compromised banking virtual machine (e.g. with viruses or rootkits) from accessing the key.

This type of approach could provide a highly secure, verifiable online banking environment.

However, the users would have to upgrade their systems to support trusted computing and virtualization, and learn to use these technologies. The TC/VM approach thus shares some of the problems already displayed by the Korean online banking system – it requires essentially proprietary software, it would lock people into a particular platform, it would deprive them of the option of doing online banking via their choice of browser and operating system, and might well display similar usability issues. (The software developers would not be benefiting from all the worldwide effort invested in browsers and the user experience generally.)

A second possible solution might be something like a bootable USB stick developed by Australia's Commonwealth Scientific and Industrial Research Organisation (CSIRO). This "Trusted Extension Device" [41] allows a trustworthy environment to be initiated from any untrustworthy one. The trustworthy environment is defined and enforced by the issuer. Trust is established with a remote bank server through trusted computing attestation where both ends authenticate each other based on their integrity reports. If attestation is successful, the banking software built into the Trust Extension Device and the remote server perform further transactions through a secure communication channel.

This approach too has drawbacks. Each bank would create their own portable devices and distribute them to customers. A customer may have many accounts with different banks, and could end up keeping track of several devices. More costs arise when such devices need to be updated and patched: the banks would have to redistribute the devices and maintain a revocation list of compromised (or out-of-date) ones.

A third possible solution might be to combine the USB idea with the idea underlying the CAP readers used in Britain and elsewhere [22]. The CAP reader accepts a smartcard (bank customers worldwide are being issued with these under the EMV programme) which can be used not just to generate OTP codes for logon but also to authenticate transactions using a MAC generated by a secret key in the smartcard. The main limitation of the CAP devices deployed in Europe is the lack of a connection to the PC: they are free-standing handheld devices into which the customer must retype transaction data. This retyping is clunky; many banks don't use it, while others only insist on it for high-risk transactions. The way to fix this is to make a 'CAP v 2' with a USB connection to the PC. Then, transaction data could be exported from the PC to the smartcard via the CAP and properly authenticated (with traffic protected by a MAC, for example). In this way each user could have a single USB CAP device into which he would plug the bank card issued on whatever account he wished to use online. A USB smartcard reader with a display and keypad might cost $10–20 if manufactured in quantity.

Something like the third option is, in our view, the most sensible medium-term solution to the problem of getting a complete, secure online banking solution into the hands of users at an acceptable cost – both in terms of the captial expenditure required by banks and the burden of usability and compatibility that they impose on their customers. Hence, if online bank fraud should get significantly worse, we would recommend that such options should be evaluated carefully.

6 Conclusion

Korean banking offers an interesting natural experiment. While most banks worldwide offer online services to their mass of retail customers via web browsers, banks in Korea have for ten years insisted that customers use proprietary encryption software that is based on ActiveX controls, together with antivirus, firewall and keylogging countermeasures.

The effects have been rather mixed. On the one hand, Microsoft's Internet Explorer has an almost complete monopoly in Korea, as customers can't do banking using Firefox or Opera. In addition, the Korean strategy is unpopular. Through an online user survey of people who have

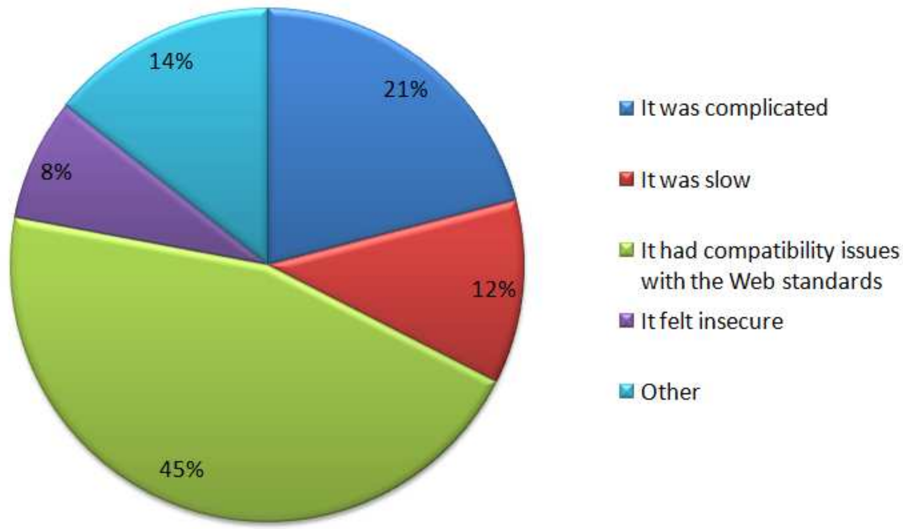

Figure 6: Why Did You Feel Uncomfortable Using the Korean Banking Service?

used both Korean and other banking services, we have shown that 68.9% of the participants felt uncomfortable using Korean services, mainly due to their complexity and lack of compatibility with the web standards (see Figure 6). (On the other hand, most customers thought Korean systems more secure, even though they aren't really – presumably because they associate security with annoying complexity.)

At the technical level, we have argued that the proprietary security software offers at best a modest improvement to overall security, and certainly cannot achieve a trustworthy user platforms. We have recommended that the banks should minimize the number of external plugins required by replacing their proprietary solutions with SSL/TLS. The installation of additional security software should be made optional for those wanting to use different web browsers. The associated risks should be communicated in a comprehensible manner so that the users can make their own security decisions.

The lessons learned in Korea may have much wider application. When security researchers discuss what options there might be if online bank fraud gets much worse, one of the possibilities is the use of proprietary systems are software – from variants on the 'trusted computing' theme to virtualization and proprietary bank client software. The Korean experience suggests that these should be treated with caution: the usability and compatibility costs they impose on users are likely to be nontrivial, and they may indeed be unacceptable (and undeployable in competitive markets). A more useful way forward may be to provide a separate trusted platform in the form of a CAP-like smartcard reader, with a trustworthy keyboard and display, into which the customer can insert her bank card to authenticate transactions.

In future work, we intend to conduct a threat and risk analysis on Korean Internet banking systems by studying the attack trends and evaluating their severity and likelihood. Very few countries publish full bank fraud figures (in Europe, only Britain, France and the Netherlands do); Korea is not yet among them. We recommend that the government publish robust electronic crime statistics, as was for example recommended in a 2008 report to ENISA for the case of European banks [42]. In the meantime, perhaps a crime victim survey can compare customers' experiences across countries. We believe that inter-country comparisons are important to define the security requirements and determine whether in fact it is necessary to invest in a next generation of online banking security technology.

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References

[1] The Bank of Korea (2009).
URL http://eng.bok.or.kr/

[2] SatCounter GlobalStats (2009).
URL http://gs.statcounter.com/

[3] Microsoft, Description of ActiveX Technologies (2007).
URL http://support.microsoft.com/kb/154544

[4] G. Kanai, the cost of monoculture (2007).
URL http://blog.mozilla.com/gen/

[5] Korean Home-brew on the Web (2007).
URL http://webstandards.or.kr/

[6] A. J. Menezes, P. C. van Oorschot, S. A. Vanstone, Handbook of Applied Cryptography, CRC Press, 2001.

[7] T. Dierks, C. Allen, The TLS Protocol Version 1.0, RFC 2246 (Informational) (1999).

[8] A. Hiltgen, T. Kramp, T. Weigold, Secure Internet Banking Authentication, IEEE Security and Privacy 4 (2) (2006) 21–29.

[9] J. Claessens, V. Dem, D. D. Cock, B. Preneel, J. Vandewalle, On the Security of Today's Online Electronic Banking Systems, Computers and Security 21 (3) (2002) 253 – 265.

[10] Y. T. Chang, Dynamics Of Banking Technology Adoption : An Application To Internet Banking, Tech. rep. (2003).

[11] Secure Electronic Transaction LLC, SET Secure Electronic Transaction Specification — Version 1.0 (May 1997).

[12] H. Lee, S. Lee, J. Yoon, D. Cheon, J. Lee, The SEED Encryption Algorithm, RFC 4269 (Informational) (December 2005).
URL http://www.ietf.org/rfc/rfc4269.txt

[13] M. Blaze, W. Diffie, R. L. Rivest, B. Schneier, T. Shimomura, E. Thompson, M. Wiener, Minimal Key Lengths for Symmetric Ciphers to Provide Adequate Commercial Security, Tech. rep. (January 1996).

[14] RedTeam, iTAN Online-banking Security System. CAN-2005-2779 (2005).
URL http://www.redteam-pentesting.de/advisories/

[15] RSA Laboratories, PKCS #5: Password-Based Encryption Standard (1993).

[16] N. Provos, D. McNamee, P. Mavrommatis, K. Wang, N. Modadugu, The Ghost in the Browser Analysis of Web-based Malware, in: HotBots'07: Proceedings of the first conference on First Workshop on Hot Topics in Understanding Botnets, USENIX Association, Berkeley, CA, USA, 2007, pp. 4–4.

[17] D. Forte, Anatomy of a Phishing Attack: A High-level Overview, Network Security 2009 (4) (2009) 17 – 19.

[18] C. Ellison, B. Schneier, Ten Risks of PKI: What You're not Being Told about Public Key Infrastructure, Computer Security Journal 16 (1) (2000) 1–7.

[19] D. Grawrock, The Intel Safer Computing Initiative, Intel Press, 2006, Ch. 1–2, pp. 3–31.

[20] H. Yin, D. Song, M. Egele, C. Kruegel, E. Kirda, Panorama: Capturing System-wide Information Flow for Malware Detection and Analysis, in: CCS '07: Proceedings of the 14th ACM Conference on Computer and Communications Security, ACM, New York, NY, USA, 2007, pp. 116–127.

[21] F. Cohen, Computer Viruses: Theory and Experiments, Computers and Security 6 (1) (1987) 22–35.

[22] S. Drimer, S. J. Murdoch, R. Anderson, Optimised to fail: Card readers for online banking, in: Financial Cryptography and Data Security, 2009.

[23] L. C. Paulson, Inductive analysis of the internet protocol tls, ACM Transactions on Information and System Security (TISSEC) 2 (3) (1999) 332–351.

[24] L. D. Bisel, The Role of SSL in Cybersecutiry, IT Professional 9 (2) (2007) 22–25.

[25] D. Wagner, B. Schneier, Analysis of the SSL 3.0 protocol, in: WOEC'96: Proceedings of the 2nd conference on Proceedings of the Second USENIX Workshop on Electronic Commerce, USENIX Association, Berkeley, CA, USA, 1996, pp. 29–40.

[26] J. C. Mitchell, Finite-State Analysis of Security Protocols, in: CAV '98: Proceedings of the 10th International Conference on Computer Aided Verification, Springer-Verlag, London, UK, 1998, pp. 71–76.

[27] M. Steiner, U. D. Saarlandes, P. Buhler, T. Eirich, M. Waidner, Secure Password-Based Cipher Suite for TLS, in: Proceedings of Network and Distributed Systems Security Symposium, 2001, pp. 134–157.

[28] D. Dean, A. Stubblefield, Using Client Puzzles to Protect TLS, in: SSYM'01: Proceedings of the 10th Conference on USENIX Security Symposium, USENIX Association, Berkeley, CA, USA, 2001, pp. 1–1.

[29] A. Hess, J. Jacobson, H. Mills, R. Wamsley, K. E. Seamons, B. Smith, Advanced Client/Server Authentication in TLS, in: Proceedings of Network and Distributed Systems Security Symposium, 2002.

[30] P. Burkholder, SSL Man-In-The-Middle Attacks, Tech. rep. (2002).

[31] S. Vaudenay, Security Flaws Induced by CBC Padding - Applications to SSL, IPSEC, WTLS ..., in: EUROCRYPT '02: Proceedings of the International Conference on the Theory and Applications of Cryptographic Techniques, Springer-Verlag, London, UK, 2002, pp. 534–546.

[32] D. Brumley, D. Boneh, Remote Timing Attacks Are Practical, in: SSYM'03: Proceedings of the 12th Conference on USENIX Security Symposium, USENIX Association, Berkeley, CA, USA, 2003, pp. 1–14.

[33] V. Klima, O. Pokorny, T. Rosa, Attacking RSA-based Sessions in SSL/TLS, in: Cryptographic Hardware and Embedded Systems (CHES), 2003, Springer, 2003, pp. 426–440.

[34] G. V. Bard, A Challenging but Feasible Blockwise-Adaptive Chosen-Plaintext Attack on SSL, in: Proceedings of the International Conference on Security and Cryptography, 2006, pp. 99–109.

[35] The Royal Bank of Scotland, Staying safe online (2010).

[36] RSA Laboratories, PKCS #11 v2.30: Cryptographic Token Interface Standard (2009).

[37] Microsoft, Cryptography API (2009).

[38] A.-R. Sadeghi, C. Stüble, Taming "Trusted Platforms" by Operating System Design, in: Information Security Applications, Vol. 2908, Lecture Notes in Computer Science, 2004, pp. 1787–1801.

[39] Xen Source, Xen: Enterprise Grade Open Source Virtualization a XenSource White Paper, Tech. rep. (2005).
URL `http://xen.xensource.com/files/xensource_wp2.pdf`

[40] D. Kuhlmann, S. L. Presti, G. Ramunno, D. Vernizzi, E. Bayer, B. Gngren, Private Electronic Transaction (PET) Proof-of-concept Prototype Documentation (March 2008).

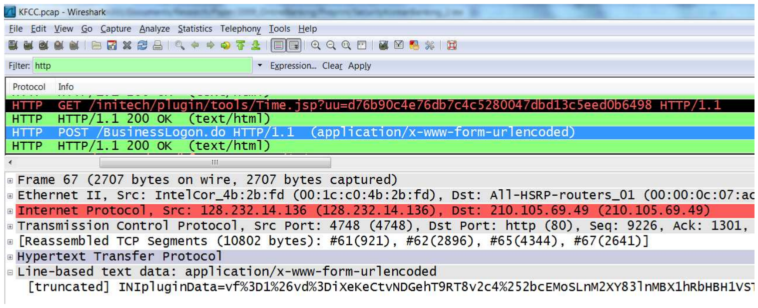
[41] S. Nepal, J. Zic, H. Hwang, D. Moreland, Trust Extension Device: Providing Mobility and Portability of Trust in Cooperative Information Systems, in: On the Move to Meaningful Internet Systems 2007: CoopIS, DOA, ODBASE, GADA, and IS, Vol. 4803/2010, Lecture Notes in Computer Science, 2007, pp. 253–271.

[42] R. Anderson, R. Böehme, R. Clayton, T. Moore, Security Economics and the Internal Market, Tech. rep., The European Network and Information Security Agency (2008).

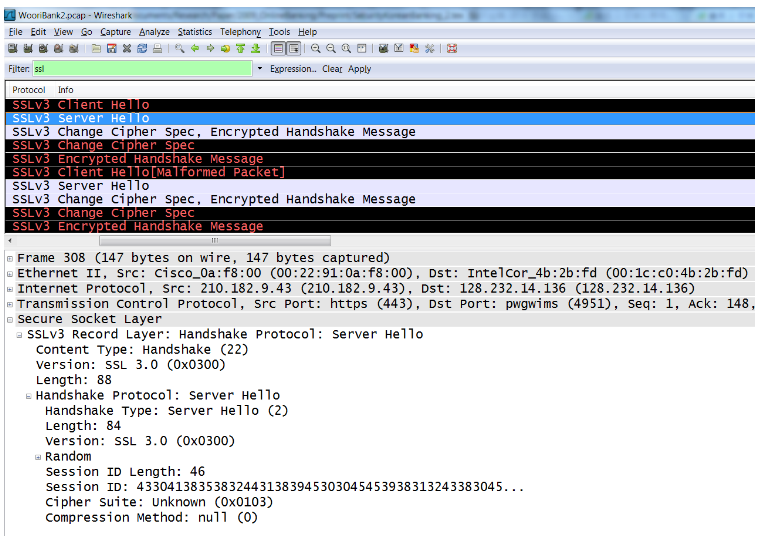
Appendix

A Examples of traffic

We analysed two key establishment protocols offered by different vendor companies, protocol 1 and protocol 2. See Figure 7.



(a) Protocol 1



(b) Protocol 2

Figure 7: Examples of traffic

In protocol 1, the user's certificate and the session key encrypted with the server's public key are delivered to the banking server using the HTTP "POST" method. We briefly describe this with the following notation. The symbols C and B represent the client software and bank server, respectively. For data input y, $S_X(y)$ and $P_X(y)$ denote the data values resulting, respectively, from the signature operation on y using X's private signing key, and the encryption operation on y party X's public encryption key. t_X is a timestamp generated by X. $cert_X$ is a certificate binding X to a public key suitable for both encryption and signature verification. E is a symmetric encryption algorithm (e.g., SEED). $k_{X_1X_2}$ is a secret symmetric session key to be shared by X_1 and X_2.

$$
\begin{aligned}
(M_1)\ B \longrightarrow C: &\quad cert_B, t_B \\
(M_2)\ C \longrightarrow B: &\quad cert_C, P_B(t_B, k_{BC}), S_C(cert_C, P_B(t_B, k_{BC})), \\
&\quad E_{k_{BC}}(cert_C, P_B(t_B, k_{BC}), S_C(cert_C, P_B(t_B, k_{BC})))
\end{aligned}
$$

Protocol 2 is almost the same as the RSA-based SSL/TLS [25, 7] except SEED is used for encryption.