How vulnerable are the Indian banks: A cryptographers’ view

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Abstract

With the advent of e-commerce and online banking it has become extremely important that the websites of the financial institutes (especially, banks) implement up-to-date measures of cyber security (in accordance with the recommendations of the regulatory authority) and thus circumvent the possibilities of financial frauds that may occur due to vulnerabilities of the website. Here, we systematically investigate whether Indian banks are following the above requirement. To perform the investigation, recommendations of Reserve Bank of India (RBI), National Institute of Standards and Technology (NIST), European Union Agency for Network and Information Security (ENISA) and Internet Engineering Task Force (IETF) are considered as the benchmarks. Further, the validity and quality of the security certificates of various Indian banks have been tested with the help of a set of tools (e.g., SSL Certificate Checker provided by Digicert and SSL server test provided by SSL Labs). The analysis performed by using these tools and a comparison with the benchmarks, have revealed that the security measures taken by a set of Indian banks are not up-to-date and are vulnerable under some known attacks.

1 Introduction

Indian economy is one of the largest and fastest growing economy of the world, and with the recent initiatives of the government, it is moving towards complete digitization. In a digital economy, secrecy of the exchanged information would play a crucial role. In India, several steps have been taken by the banks and government agencies for the orientation of the end users and thus to reduce the risk of simple frauds that originate due to the mistakes of the users. However, there is another facet of the security of e-commerce, which involves the service providers and requires that the banks provide highest possible security without becoming slow. To ensure that the Reserve Bank of India (RBI), which regulates Indian banks have issued several circulars [1,2], and have advised Indian banks to use up-to-date encryption techniques [1–3]. Here, we aim to check, to what extend the Indian banks follow the advices issued by the RBI and in what cases the security measures taken by the banks are vulnerable. We would also suggest some solutions for the safe operations of the e-banking portals in the present and future. This investigation would remain focused on the Indian banks, and would aim to reveal such cases where the security measures taken by the Indian banks are not up-to-date and are vulnerable under some known attacks. To reveal these vulnerabilities, we will adopt a more technical approach compared to the earlier studies on the security of Indian banks and customer perspectives about that [4–6]. Specifically, the validity and quality of the security certificates of various Indian banks will be tested here with the help of a set of tools (e.g., SSL Certificate Checker provided by Digicert and SSL server test provided by SSL Labs). The analysis performed by using these tools and a comparison with the benchmarks, have revealed that the encryption techniques used by many Indian banks are vulnerable. The uniqueness of the present study is that to the best of our knowledge, no such technical analysis of the encryption mechanism adopted by the Indian banks has been done until now.

We have already mentioned that the security and privacy issues of Indian banks have been studied earlier [4–6], but a less technical view was adopted. Specifically, in Ref [4], possible attacks on customers’ information like phishing, spoofing, vishing had been mentioned. Some efforts had also been made to discuss card-related frauds, merchant-related frauds, but no efforts had been made to investigate the vulnerability of the banks. In another
study in the similar line (but not restricted to Indian banks) \cite{7}, various dimensions of e-service security had been listed and utilized to obtain a hierarchical structure of them to compute the weights of security dimensions. Once again, the analysis was more focused on the perspectives of the end users and led a trivial conclusion that “users will intend to use e-service if they feel that the quality of e-service is high”. The same conclusion regarding the behavior of end users has recently been reported again by Taherdoost in \cite{8} through E-Service Technology Acceptance Model (ETAM) which can evaluate the user acceptance of e-service technology even before the introduction of the service. Such studies on the acceptability of an e-service by the end users is not new. In a set of earlier studies \cite{9,19}, similar investigations have been made. However, the important question: Which technical (cryptographic) measures taken by the bank can improve the security of e-service and thus lead to enhanced confidence among the end users had not been discussed in the earlier works. The present work aims to go beyond technology acceptance model and to address this issue by highlighting the limitations of the security measures taken by different banks.

The rest of the paper is organized as follows. In Section 2 we perform the vulnerability analysis of Indian banks and establish that the encryption used by Indian banks are often vulnerable. In Section 3 we compare the encryption techniques adopted by the Indian banks with the international standards and analyze them in view of the recommendations of RBI. The comparison, has revealed that many banks are not strictly following RBI guidelines and thus prone to cyber attacks. Subsequently, in Section 4 we suggest a set of measures that can be adopted by Indian banks to avoid the use of vulnerable encryption techniques in future. Finally, the paper is concluded in Section 5.

2 Vulnerability analysis

The SSL client certificates are obtained by the banks from different certifying agencies (CA) like, Symantec Corporation, DigiCert Inc., and Corporation Service Company. These organizations are allowed to issue SSL client certificate. The online banking websites contain details of the certificates obtained by the banks and the validity of the certificate. It also provides certified information about the encryption and authentication method used by the bank to encrypt information before being transmitted over the internet. The quality of these encryption methods can be analyzed to some extent by looking at the string like, “TLS_ECDHE_RSA_WITH_AES_256_GCM_SHA384, 256 bit keys, TLS 1.2”, which are obtained directly from the security certificate information of the banking website. A full list of strings describing the encryption and the authentication methods adopted by different banks are provided in Table A.1 of Appendix A. Further, information about the quality of the encryption technique adopted and their potential vulnerability can be obtained by performing various tests on SSL servers and/or SSL certificates. Some of the online SSL certificate checking tools that may be used to reveal the potential vulnerability of the adopted encryption technique are available at \cite{20–23}. In what follows, we report and analyze the results of SSL server tests performed by SSL Labs \cite{20}. These tests not only reveal the potential vulnerability it also grades the servers according to their strength. A server graded as A+ seems to be most strong, whereas a server graded as F is considered to be the weakest or most vulnerable. We have analyzed the security of 38 banks using \cite{20}. The result is summarized in Fig. 1 (a)-(b), where Fig. 1 (a) provides the number distribution of grades obtained by different Public (Government controlled) banks and Fig. 1 (b) provides the same information for the private banks. Fig. 1 (a)-(b), shows that 13 of the 38 banks obtained A, A+, and A- grades, and they may be viewed to provide relatively higher security. Similarly, the analysis has shown that B and C grades have been obtained by 8 and 9 banks respectively. Thus, we may conclude that these banks provide moderate security. Finally, remaining 8 banks are found to obtain F grade, and they are highly vulnerable, implying the fact that the security measure taken by them is very weak. There are many reasons that lead to the security weaknesses of this banks. Such weaknesses are characterized by performing various vulnerability tests and summarized in Tables 1-3. Details of the insecure SSL ciphers supported by the server of the banks and other drawbacks of these banks are summarized in these tables. Specifically, Table 1 is focused on the analysis of security of those banks that are reasonably secure (obtains A, A+ or, A- grades).

Table 2 and Table 3 summarizes the security analysis performed for the banks with moderate security (Grades B and C) and those with weak security measures (Grade F), respectively. In a similar line, security analysis performed for popular wallets provided by non-Banking organizations are reported in Table 4. While analyzing the limitations of the security measures taken by a bank, in addition to the results of analysis performed by \cite{20}, we have also used the outcome of analysis performed by \cite{21}, which essentially tests “Heartbleed vulnerability”, checks whether the server supports backdated protocols like TLS 1.0, TLS 1.1, SSL 3.0, etc., looks for known vulnerable Debian keys and lists all the SSL ciphers supported by the server. This list is subsequently used to detect whether the server supports insecure ciphers. The outputs of analysis performed using \cite{20,21} are combined in Tables 1-4. Here it may be noted that in Table 4 we review the security provided by the most popular non-bank wallets used for e-commerce by Indians. The analysis performed through \cite{20,21} has revealed that various banks use vulnerable
ciphers, specially some of them are found to use keys of inadequate length, support RC4 cipher with older protocols, support TLS 1.0, TLS 1.1, SSL 3.0, etc., and to be vulnerable to Padding Oracle On Downgraded Legacy Encryption (POODLE) attack (Allahabad Bank, Canara Bank, Indusind Bank and Punjab National Bank) and to man-in-the-middle attack (MITM) (Bank of Baroda, Syndicate Bank, Indusind Bank). Here, it may be apt to note that POODLE is a particular type of MITM attack that exploits internet and security software clients’ fallback to SSL 3.0. These observations are illustrated through Fig. (c), and summarized in Table A.II of Appendix A.

| S.No | Name of the bank (Pub/Pvt) | Website | Server (Grade) | Remarks |
|------|---------------------------|---------|----------------|---------|
| 1    | State Bank of India (Pub)  | retail.onlinesbi.com | 223.31.160.67 (A+) 2405:a700:14:12c:0:0:0:148 (A+) | (i) HTTP Strict Transport Security (HSTS) with long duration deployed on this server. |
| 2    | Axis Bank (Pvt)            | retail.axisbank.co.in | 121.243.50.21 (A) 2403:0:500:11:0:0:0:160 (A) | |
| 3    | Andhra Bank (Pub)          | www.online andhrabank.net.in | 103.196.117.1 (A) | |
| 4    | Catholic Syrian Bank (Pvt) | www.csbnet.co.in | 115.112.233.198 (A) | |
| 5    | HDFC Bank (Pvt)            | netbanking.hdfcbank.com | 175.100.160.21 (A) | (i) Intermediate certificate has an insecure signature. (ii) HTTP Strict Transport Security (HSTS) with long duration deployed on this server. |
| 6    | Indian Bank (Pub)          | www.indianbank.net.in | 115.110.173.99 (A-) | (i) Intermediate certificate has an insecure signature. |
| 7    | Oriental Bank of Commerce (Pub) | www.obconline.co.in | 220.226.206.37 (A-) | (i) Forward Secrecy with the reference browsers is not supported. (ii) HTTP Strict Transport Security (HSTS) with long duration deployed on this server. |
| 8    | UCO Bank (Pub)             | www.ucoebanking.com | 203.200.206.227 (A-) 2405:a080:0:0:0:0:0:30 (A-) | (i) Secure renegotiation is not supported. (ii) Forward Secrecy with the reference browsers is not supported. |
| 9    | United Bank of India (Pub) | ebank.unitedbank ofindia.com | 14.142.120.11 (A-) | |
| 10   | ICICI Bank (Pvt)           | infinity.icicibank.com | 203.189.92.162 (A-) 2001:d10:2fd:1:0:0:2 (A-) | (i) Secure renegotiation is not supported. (ii) Forward Secrecy with the reference browsers is not supported. |
| 11   | Karnataka Bank (Pvt)       | moneyclick.karnatakabank.co.in | 210.212.203.235 (A-) 125.16.142.105 (A-) 2404:a800:3001:b:0:0:0:5 (A-) | (i) Forward Secrecy with the reference browsers is not supported. |
| 12   | RBL Bank (Pvt)             | online.rblbank.com | 180.179.110.171 (A-) | (i) Secure renegotiation is not supported. (ii) Forward Secrecy with the reference browsers is not supported. |
Table 1: List of banks that provide reasonably good security in the sense that they obtain grades $\in \{A+, A, A-\}$

| S. No | Name of the bank (Pub/Pvt) | Website | Server (Grade) | Issues that reduced the grade |
|-------|-----------------------------|---------|----------------|-------------------------------|
| 1     | Vijaya Bank (Pub)           | www.vijayabankonline.in | 210.212.204.30 (B) 219.65.65.166 (B) 2403:0:500:31:0:0:12 (B) | (i) Accepts RC4 cipher, but only with older protocols. (ii) Forward Secrecy with the reference browsers is not supported. |
| 2     | Bank of India (Pub)         | starconnectcbs.bankofindia.com | 61.246.202.9 (B) | (i) Supports weak Diffie-Hellman (DH) key exchange parameters. (ii) Forward Secrecy with the reference browsers is not supported. |
| 3     | Indian Overseas Bank (Pub)  | www.iobnet.co.in | 121.242.125.68 (B) | (i) Uses SSL 3, which is obsolete and insecure. (ii) Accepts RC4 cipher, but only with older protocols. (iii) Forward Secrecy with the reference browsers is not supported. |
| 4     | IDBI Bank Ltd (Pub)         | inet.idbibank.co.in | 103.93.45.42 (B) 2001:df1:3700:1:0:0:0:7 (B) | (i) Accepts RC4 cipher, but only with older protocols. (ii) Secure renegotiation is not supported. (iii) Forward Secrecy with the reference browsers is not supported. |
| 5     | DCB Bank (Pvt)              | pib.dcbbank.com | 202.56.244.126 (B) 203.196.200.194 (B) | (i) Accepts RC4 cipher, but only with older protocols. (ii) Forward Secrecy with the reference browsers is not supported. |
| 6     | Fednet Internet Banking (Pvt) | www.fednetbank.com | 121.243.127.68 (B) | (i) Accepts RC4 cipher, but only with older protocols. (ii) Forward Secrecy with the reference browsers is not supported. |
| 7     | IDFC Bank (Pvt)             | my.idfcbank.com | 103.233.77.139 (B) | (i) Supports weak Diffie-Hellman (DH) key exchange parameters. (ii) Forward Secrecy with the reference browsers is not supported. |
|   | Bank Name                        | Website                        | IP Address                  | Vulnerabilities                                                                 |
|---|----------------------------------|--------------------------------|-----------------------------|--------------------------------------------------------------------------------|
| 8 | Lakshmi Vilas Bank (Pvt)         | www.lvbankonline.in            | 121.243.113.251 (B)         | (i) Accepts RC4 cipher, but only with older protocols. (ii) Forward Secrecy with the reference browsers is not supported. |
| 9 | Allahabad bank (Pub)             | www.allahabadbank.in           | 2401:8800:70:1:0:0:2 (C)    | (i) Vulnerable to the POODLE attack. (ii) Supports older protocols, but does not support the current best TLS 1.2. (iii) Accepts RC4 cipher, but only with older protocols. |
| 10| Central Bank of India (Pub)      | www.centralbank.net.in         | 223.30.146.175 (C) 112.133.218.235 (C) | (i) Vulnerable to the POODLE attack. (ii) Accepts RC4 cipher, but only with older protocols. (iii) Forward Secrecy with the reference browsers is not supported. |
| 11| Dhan Bank (Pvt)                  | netbank.dhanbank.in            | 115.117.58.155 (C) 59.144.54.55 (C) | (i) Uses SSL 3, which is obsolete and insecure. (ii) Uses RC4 with modern protocols. (iii) Forward Secrecy with the reference browsers is not supported. |
| 12| Punjab And Sind Bank (Pub)       | www.psbonline.co.in            | 202.191.179.43 (C)          | (i) Accepts RC4 cipher, but only with older protocols. (ii) Uses 64-bit block cipher (3DES / DES / RC2 / IDEA) with modern protocols. (iii) Forward Secrecy with the reference browsers is not supported. |
| 13| J & K Bank (Pvt)                 | www.jkbankonline.com           | 223.30.216.170 (C)          | (i) Supports weak DH key exchange parameters. (ii) Uses SSL 3, which is obsolete and insecure. (iii) Uses RC4 with modern protocols. (iv) Forward Secrecy with the reference browsers is not supported. |
| 14| Karur Vysya Bank (Pvt)           | www.kvbnet.co.in               | 115.249.239.101 (C)         | (i) Accepts RC4 cipher, but only with older protocols. (ii) Uses 64-bit block cipher (3DES / DES / RC2 / IDEA) with modern protocols. (iii) Forward Secrecy with the reference browsers is not supported. |
| S. No | Name of the bank (Pub/Pvt) | Website | Server(s) (Grade) | Issues that reduced the grade |
|------|---------------------------|---------|-------------------|-------------------------------|
| 1    | Canara Bank (Pub)         | netbanking.canarabank.in | 180.92.164.8 (F) 2404:a500:0:1000:0:0:60:e (F) | (i) Vulnerable to MITM attacks because it supports insecure renegotiation. (ii) Forward Secrecy with the reference browsers is not supported. |
| 2    | Corporation Bank (Pub)    | www.corpretail.com        | 202.62.247.23 (F)  | (i) Supports anonymous (insecure) suites and other insecure cipher suites (ii) Supports weak DH key exchange parameters. |
| 3    | Dena Bank (Pub)           | www.denaiconnect.co.in    | 103.224.110.30 (F) | (i) Supports insecure cipher suites (see below for details). (ii) Supports 512-bit export suites and might be vulnerable to the FREAK attack. (iii) Intermediate certificate contains an insecure signature. (iv) Supports older protocols, but does not support the current best TLS 1.2. (v) Forward Secrecy with the reference browsers is not supported. (vi) Accepts RC4 cipher, but only with older protocols. |

Table 2: List of banks that provide moderate security in the sense that they obtain grades $\in \{B, C\}$. 
| S. No | Name of the bank               | Website                  | Server (Grade)                  | Issues that reduced the grade                                                                 |
|-------|-------------------------------|--------------------------|--------------------------------|------------------------------------------------------------------------------------------------|
| 1     | Paytm payments bank           | paytm.com                | 52.221.159.215 (A+) 52.77.12.221 (A+) | HTTP Strict Transport Security (HSTS) with long duration deployed on this server.                  |
| 2     | Airtel payments bank          | www.airtel.in            | 23.13.173.139 (B)          | This server accepts RC4 cipher, but only with older protocols. Grade capped to B.                |
### Table 4: Security analysis of the wallets that are popularly used in India.

| No. | Wallet   | Website            | IPv4 Address          | IPv6 Address          |
|-----|----------|--------------------|-----------------------|-----------------------|
| 3   | Freecharge | www.freecharge.in | 2600:1408:10:1a8:0:0:0:1c64 (A) | 23.49.179.215 (A) |
|     |          |                    | 2600:1408:10:1ae:0:0:0:1c64 (A) |                       |
| 4   | Mobikwik  | www.mobikwik.com   | 180.179.23.136 (A)    | 2401:8800:c11:3:0:0:4 (A) |

3 Comparison of the encryption techniques used with the benchmark adopted internationally and advised by the regulatory authority

In Point 6 of RBI circular [1], it is categorically mentioned in the context of arrangement for continuous surveillance, that “Testing for vulnerabilities at reasonable intervals of time is very important. The nature of cyber-attacks are such that they can occur at any time and in a manner that may not have been anticipated. Hence, it is mandated that a SOC (Security Operations Centre) be set up at the earliest, if not yet been done. It is also essential that this Centre ensures continuous surveillance and keeps itself regularly updated on the latest nature of emerging cyber threats”. The analysis performed above clearly indicates that most of the Indian banks are not following this recommendation of RBI as they are still using vulnerable and backdated ciphers. Further, in the same context (i.e., in the context of vulnerability), in Ref. [2] Page 31, Section 16, RBI has clearly emphasized on the necessity of regular vulnerability tests by stating the following, “… Banks that do not scan for vulnerabilities and address discovered flaws proactively face a significant likelihood of having their computer systems compromised. ii. The following are some of the measures suggested:

- Automated vulnerability scanning tools need to be used against all systems on their networks on a periodic basis, say monthly or weekly or more frequently.
- Banks should ensure that vulnerability scanning is performed in an authenticated mode (i.e., configuring the scanner with administrator credentials) at least quarterly, ...

It’s clear that many banks are not strictly following this advise of RBI. In Ref. [2] Page 29, Section 14, point (v), in the context of encryption, RBI has advised banks as follows, “Normally, a minimum of 128-bit SSL encryption is expected. Constant advances in computer hardware, cryptanalysis and distributed brute force techniques may induce use of larger key lengths periodically. It is expected that banks will properly evaluate security requirements associated with their internet banking systems and other relevant systems and adopt an encryption solution that is commensurate with the degree of confidentiality and integrity required. Banks should only select encryption algorithms which are well established international standards and which have been subjected to rigorous scrutiny by an international cryptographer community....”. Now although RBI is recommending a minimum of 128-bit SSL encryption, it is found that Kayur Vashiya Bank, Dena Bank, Kotak Mahinrda, The South Indian Bank, Punjab and Sind bank, etc., are still providing 112 bit encryption which is bellow the recommended norm. If we further concentrate on the last part of the RBI advise that recommends the use of “encryption algorithms which are well established international standards and which have been subjected to rigorous scrutiny by an international cryptographer community”, we would easily realize that Bank should now follow at least 256-bit encryption to be consistent with the international standards (i.e., recommendations of NIST, ENISA and IETF [24–26]), and stop supporting SHA, SHA-1, SHA-224, TLS 1.0, TLS 1.1 and other vulnerable ciphers mentioned above. In fact banks should now start using TLS 1.3 as it is faster than TLS 1.2 and it has many advantages over TLS 1.2. Further, recently IETF has approved TLS 1.3 as the next version of TLS protocols [27].

4 Measures suggested to circumvent the vulnerability of encryption techniques in future

Banks should immediately stop supporting vulnerable ciphers. In the next phase, they should implement post-quantum cryptographic protocols like, lattice-based, multivariate, code-based, hash-based cryptography, and

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4 Recently stopped using 112 bit encryption  
5 IETF is the body that is authorized to approve internet standards and protocols. The recommendation of IETF for the algorithms to be used for practical application are valid only for a period of six months, and consequently, it’s important to update the security measures taken by a bank at least once in every six months.
Figure 1: (a) Number distribution of grades obtained by different public banks, (b) Number distribution of grades obtained by different private banks, (c) Number distribution of the Public banks showing a particular characteristic of vulnerability (weakness), (c) Number distribution of the Private banks showing a particular characteristic of vulnerability (weakness).
replace the random number generators by quantum random number generators \cite{29} and thus go for a hybrid (classical-quantum) technology. Subsequently, they should look at the possibilities of implementing semi-quantum \cite{30,31} protocols which would require end users (customers) to have quantum resources which are costly. A final goal should be to implement unconditionally secure and device independent quantum schemes \cite{32,33}.

5 Conclusions

Most of the Indian banks are found to support insecure SSL ciphers. Some of the previous studies were restricted to the banks of specific region or country (e.g., investigations performed in Refs \cite{4,10,11,15,17,19} were restricted to the banks of India, Hongkong and Malyasia, respectively), whereas others were not restricted. Present study is also focused on Indian banks, but the methodology adopted and the conclusions obtained are valid in general. To emphasis on this point we analyze the security of 11 non-Indian banks, which are selected from different continents. In what follows, we briefly note the outcome of such an investigation in Table 5.

| S. No | Name of the bank (Country) | Website | Server (Grade) | Issues that reduced the grade |
|-------|--------------------------|---------|---------------|-----------------------------|
| 1     | Bank of America (USA)    | https://secure.bankofamerica.com/ | 171.161.203.200 (A-) | This server does not support Forward Secrecy with the reference browsers. Grade will be capped to B from March 2018. This server’s certificate will be distrusted by Google and Mozilla from September 2018. HTTP Strict Transport Security (HSTS) with long duration deployed on this server. |
| 2     | jpmorgan chase (USA)     | www.chase.com | 159.53.224.21 (A-) | This server does not support Forward Secrecy with the reference browsers. Grade will be capped to B from March 2018. HTTP Strict Transport Security (HSTS) with long duration deployed on this server. |
| 3     | Bank of Brazil (Brazil)  | www.bb americas.com | 52.84.237.182 (A) 52.84.237.72 (A) 52.84.237.12 (A) 52.84.237.180 (A) 52.84.237.121 (A) 52.84.237.77 (A) 52.84.237.80 (A) 52.84.237.203 (A) | |
| 4     | Steward Bank (Zimbabwe) | onlinebanking. stewardbank.co.zw | 41.216.125.233 (B) | This server supports weak Diffie-Hellman (DH) key exchange parameters. Grade capped to B. This site works only in browsers with SNI support. |
| 5     | Avtovaz bank (Russia)    | server29.ceyebanking.com | 12.191.20.25 (C) | The server supports only older protocols, but not the current best TLS 1.2. Grade capped to C. This server does not support Forward Secrecy with the reference browsers. Grade will be capped to B from March 2018. This server does not support Authenticated encryption (AEAD) cipher suites. Grade will be capped to B from March 2018. |
|   | Bank Name                        | Website                          | IP Address                                 | Notes                                                                                                                                 |
|---|----------------------------------|----------------------------------|--------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------|
| 6 | Pingan Bank (China)              | bank.pingan.com                  | 115.231.227.16 (A) 27.148.164.23(A)        | This server’s certificate will be distrusted by Google and Mozilla from September 2018                                                 |
| 7 | Police Bank Ltd (Australia)      | ebanking.policebank.com.au       | 103.11.142.65 (A)                          | This server does not support Authenticated encryption (AEAD) cipher suites. Grade will be capped to B from March 2018.                |
| 8 | Bank of Melbourne (Australia)    | ibanking.bankofmelbourne.com.au | 203.23.44.204 (A)                          | This server is vulnerable to the Return of Bleichenbacher’s Oracle Threat (ROBOT) vulnerability. Grade will be set to F from March 2018. The server supports weak Diffie-Hellman (DH) key exchange parameters. Grade capped to B. The server uses SSL 3, which is obsolete and insecure. Grade capped to B. The server accepts RC4 cipher, but only with older protocols. Grade capped to B. The server does not support Forward Secrecy with the reference browsers. Grade will be capped to B from March 2018. This server’s certificate chain is incomplete. Grade capped to B. This server’s certificate will be distrusted by Google and Mozilla from September 2018. This server uses SSL 3 which is obsolete and insecure. Grade capped to B. This server accepts RC4 cipher, but only with older protocols. Grade capped to B from March 2018. This server does not support Forward Secrecy with the reference browsers. Grade will be capped to B from March 2018. This server’s certificate chain is incomplete. Grade capped to B. This server’s certificate will be distrusted by Google and Mozilla from September 2018. |   
| 9 | Bank Kerjasama Rakyat Berhad (Malaysia) | www2.irakyat.com.my | 1.9.61.247 (B)                              | This server supports weak Diffie-Hellman (DH) key exchange parameters. Grade capped to B. The server does not support Forward Secrecy with the reference browsers. Grade will be capped to B from March 2018. This server’s certificate chain is incomplete. Grade capped to B. This server’s certificate will be distrusted by Google and Mozilla from September 2018. |   
| 10| National Bank of Pakistan (Pakistan) | https://nbp.com.pk/login/ | 167.114.191.212 (A+)                       | This server’s certificate will be distrusted by Google and Mozilla from September 2018. HTTP Strict Transport Security (HSTS) with long duration deployed on this server. |
| 11| Agrani Bank Limited (Bangladesh) | www.agranibank.org               | 180.92.224.101 (B)                         | This server supports weak Diffie-Hellman (DH) key exchange parameters. Grade capped to B. The server does not support Forward Secrecy with the reference browsers. Grade will be capped to B from March 2018. This server’s certificate chain is incomplete. Grade capped to B. This server’s certificate will be distrusted by Google and Mozilla from September 2018. |   

Table 5: Security analysis of some non-Indian banks.

This study is unique, as it’s the first one of its kind in the context of Indian banks. However, the analysis performed is not deep enough. Consequently, it opens up the possibility of a deeper analysis in future (which will be reported elsewhere). As the adopted method is valid in general, it’s possible to use this simple approach to analyze the security of banks and other e-commerce sites of other countries, too. Finally, we conclude the article with an optimistic view and a hope that this article will be able to draw the attention of the concerned authorities, and necessary steps will be taken by them to perform regular checking of vulnerability of the encryption techniques adopted by them (as recommended by RBI) and to take corrective measures wherever required. This would help banks to provide higher security and thus to improve the confidence level of the end-users (acceptability of the end-users), which the banks desire to improve. Further, we hope that the suggestions made from the perspectives of a cryptographer will be used by the banks in near future and that would help them to circumvent many attacks in the future.

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## Appendix A

| S. No | Bank Name                          | Website                      | Connection Encrypted                        | Verified by (Certification Authority) |
|-------|------------------------------------|------------------------------|---------------------------------------------|---------------------------------------|
| 1     | Allahabad Bank                     | www.allahabadbank.in        | TLS_ECDHE_RSA_WITH_AES_256_CBC_SHA, 256 bit keys, TLS 1.0 | Symantec Corporation                  |
| 2     | Andhra Bank                        | www.onlineandhram.com       | TLS_ECDHE_RSA_WITH_AES_256_GCM_SHA384, 256 bit keys, TLS 1.2 | Entrust, Inc.                         |
| 3     | State Bank of India                | retail.onlinebank.com      | TLS_ECDHE_RSA_WITH_AES_256_GCM_SHA384, 256 bit keys, TLS 1.2 | Symantec Corporation                  |
| 4     | Axis Bank Limited                  | retail.axisbank.co.in      | TLS_ECDHE_RSA_WITH_AES_256_GCM_SHA384, 256 bit keys, TLS 1.2 | Symantec Corporation                  |
| 5     | HDFC Bank Limited                  | netbanking.hdfc.com        | TLS_ECDHE_RSA_WITH_AES_256_GCM_SHA384, 256 bit keys, TLS 1.2 | Symantec Corporation                  |
| 6     | Jammu and Kashmir Bank Limited     | starconnectcb.com          | TLS_ECDHE_RSA_WITH_AES_256_GCM_SHA384, 256 bit keys, TLS 1.2 | Symantec Corporation                  |
| 7     | Bandhan Bank Limited               | bandhanbankonline.com      | TLS_ECDHE_RSA_WITH_AES_256_GCM_SHA384, 256 bit keys, TLS 1.2 | Entrust, Inc.                         |
| 8     | Vijaya Bank                        | www.vijayabankonline.in    | TLS_ECDHE_RSA_WITH_AES_256_CBC_SHA, 256 bit keys, TLS 1.2 | Entrust, Inc.                         |
| 9     | The Catholic Syrian Bank Ltd       | www.csbnet.co.in           | TLS_ECDHE_RSA_WITH_AES_256_CBC_SHA, 256 bit keys, TLS 1.2 | Symantec Corporation                  |
| 10    | Tamilnad Mercantile Bank Limited   | www.tmbnet.in              | TLS_ECDHE_RSA_WITH_AES_256_CBC_SHA, 256 bit keys, TLS 1.2 | Symantec Corporation                  |
| 11    | Canara Bank                        | netbanking.canarabank.in   | TLS_RSA_WITH_AES_256_CBC_SHA, 256 bit keys, TLS 1.2 | GlobalSign nv-sa                       |
| 12    | Corporation Bank                   | www.corpretail.com         | TLS_RSA_WITH_AES_256_CBC_SHA, 256 bit keys, TLS 1.2 | GlobalSign nv-sa                       |
| 13    | Indian Overseas Bank               | www.jobnet.co.in           | TLS_RSA_WITH_AES_256_CBC_SHA, 256 bit keys, TLS 1.2 | Symantec Corporation                  |
| 14    | Oriental Bank of Commerce          | www.obconline.co.in        | TLS_RSA_WITH_AES_256_CBC_SHA, 256 bit keys, TLS 1.2 | Symantec Corporation                  |
| 15    | IDBI Bank Ltd                      | inet.idbibank.co.in        | TLS_RSA_WITH_AES_256_CBC_SHA, 256 bit keys, TLS 1.2 | Entrust, Inc.                         |
| 16    | United Bank of India               | ebank.unitedbankofindia.com| TLS_RSA_WITH_AES_256_CBC_SHA, 256 bit keys, TLS 1.2 | Symantec Corporation                  |
| 17    | Dhanlaxmi Bank Limited             | netbank.dhanbank.in        | TLS_RSA_WITH_AES_256_CBC_SHA, 256 bit keys, TLS 1.2 | Entrust, Inc.                         |
| 18    | ICICI Bank Limited                 | infinity.icicibank.com     | TLS_RSA_WITH_AES_256_CBC_SHA, 256 bit keys, TLS 1.2 | Entrust, Inc.                         |
| 19    | IndusInd Bank Ltd                  | indusnet.indusind.com      | TLS_RSA_WITH_AES_256_CBC_SHA, 256 bit keys, TLS 1.2 | Entrust, Inc.                         |
| 20    | RBL Bank Limited                   | online.rblbank.com         | TLS_RSA_WITH_AES_256_CBC_SHA, 256 bit keys, TLS 1.2 | Entrust, Inc.                         |
| S. No | Bank Name                      | Domain                          | Security Measures                                                                 | CA                                      |
|-------|--------------------------------|---------------------------------|------------------------------------------------------------------------------------|-----------------------------------------|
| 21    | Yes Bank Limited               | netbanking.yes_bank.co.in       | TLS_RSA_WITH_AES_256_CBC_SHA, 256 bit keys, TLS 1.2                               | Symantec Corporation                    |
| 22    | PUNJAB AND SIND BANK           | www.psbonline.co.in             | TLS_RSA_WITH_3DES_EDE_CBC_SHA, 112 bit keys, TLS 1.2                              | GlobalSign Corporation                  |
| 23    | Syndicate Bank                 | www.syndonline.in               | TLS_RSA_WITH_3DES_EDE_CBC_SHA, 112 bit keys, TLS 1.2                              | Symantec Corporation                    |
| 24    | IDFC Bank Limited              | my.idfcbank.com                 | TLS_RSA_WITH_3DES_EDE_CBC_SHA, 112 bit keys, TLS 1.2                              | Entrust, Inc.                           |
| 25    | Kotak Mahindra Bank Ltd        | www.kotak.com                   | TLS_RSA_WITH_3DES_EDE_CBC_SHA, 112 bit keys, TLS 1.2                              | Entrust, Inc.                           |
| 26    | The Karur Vysya Bank Ltd       | www.kvbnet.co.in                | TLS_RSA_WITH_3DES_EDE_CBC_SHA, 112 bit keys, TLS 1.2                              | Syntanec Corporation                   |
| 27    | The South Indian Bank Ltd      | sibernet.southindianbank.com    | TLS_RSA_WITH_3DES_EDE_CBC_SHA, 112 bit keys, TLS 1.2                              | Entrust, Inc                            |
| 28    | Bank of Baroda                 | www.bobibanking.com             | TLS_RSA_WITH_AES_128_CBC_SHA, 128 bit keys, TLS 1.0                               | Syntanec Corporation                   |
| 29    | Punjab National Bank           | netbanking.netpub.com           | TLS_RSA_WITH_AES_128_CBC_SHA, 128 bit keys, TLS 1.0                               | Syntanec Corporation                   |
| 30    | Indian Bank                    | www.indianbank.net.in           | TLS_RSA_WITH_AES_128_CBC_SHA, 128 bit keys, TLS 1.2                               | Syntanec Corporation                   |
| 31    | UCO Bank                       | www.ucoebanking.com             | TLS_RSA_WITH_AES_128_CBC_SHA, 128 bit keys, TLS 1.2                               | Syntanec Corporation                   |
| 32    | The Federal Bank Limited       | www.fednetbank.com              | TLS_RSA_WITH_AES_128_CBC_SHA, 128 bit keys, TLS 1.2                               | Syntanec Corporation                   |
| 33    | Karnataka Bank Limited         | moneyclick.karnatakabank.co.in  | TLS_RSA_WITH_AES_128_CBC_SHA, 128 bit keys, TLS 1.2                               | Syntanec Corporation                   |
| 34    | LAKSHMI VILAS BANK LIMITED     | www.lvbankonline.in             | TLS_RSA_WITH_AES_128_CBC_SHA, 128 bit keys, TLS 1.2                               | Syntanec Corporation                   |
| 35    | DCB BANK                       | pib.debbank.com                 | TLS_RSA_WITH_AES_128_CBC_SHA, 128 bit keys, TLS 1.2                               | Syntanec Corporation                   |
| 36    | Bank of India                  | starconnectchs.bankofindia.com  | TLS_DHE_RSA_WITH_AES_256_CBC_SHA, 256 bit keys, TLS 1.2                           | Entrust, Inc                           |
| 37    | Central Bank of India          | www.centralbank.net.in          | TLS_ECDHE_RSA_WITH_AES_128_CBC_SHA, 128 bit keys, TLS 1.2                         | Syntanec Corporation                   |
| 38    | Dena Bank                      | www.denaconnect.co.in           | TLS_RSA_WITH_3DES_EDE_CBC_SHA, 112 bit keys, TLS 1.0                              | Syntanec Corporation                   |

Table A.I: String that identifies the security measures taken by a bank for encryption and authentication is listed along with the name of CA who has issued the security certificate.

| S. No | Weakness                                      | Public Bank | Private Bank | Total |
|-------|-----------------------------------------------|-------------|--------------|-------|
| 1     | vulnerable to the OpenSSL Padding Oracle vulnerability | 0           | 1            | 1     |
|   |   |   |   |
|---|---|---|---|
| 2 | MITM attack | 2 | 1 | 3 |
| 3 | Forward secrecy with the reference browsers is not supported | 12 | 14 | 26 |
| 4 | supports anonymous (insecure) suites | 1 | 0 | 1 |
| 5 | supports insecure cipher suites | 1 | 0 | 1 |
| 6 | supports weak DH key exchange | 2 | 2 | 4 |
| 7 | FREAK attack | 1 | 0 | 1 |
| 8 | intermediate certificate with insecure signature | 1 | 1 | 2 |
| 9 | TLS 1.2 is not supported | 3 | 0 | 3 |
| 10 | Accepts/uses RC4 | 7 | 8 | 15 |
| 11 | Intolerant to newer protocol | 1 | 0 | 1 |
| 12 | POODEL TLS attack | 3 | 1 | 4 |
| 13 | Supports SSL3 | 4 | 3 | 7 |
| 14 | uses 64-bit block cipher (3DES / DES / RC2 / IDEA) with modern protocols | 2 | 4 | 6 |
| 15 | No support for secure renegotiation. | 2 | 3 | 5 |

Table A.II: Various vulnerable ciphers that are used by the bank with low grades.