QoS-aware Optimization Strategy for Security Ranking in SSL Protocol

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***Abstract*—The primary goal of the secure socket layer protocol (SSL) is to provide confidentiality and data integrity between two communicating entities. Since the most computationally expensive step in the SSL handshake protocol is the server's RSA decryption, it is introduced that the proposed secret exchange algorithm can be used to speedup SSL session initialization. The optimization strategy, which is based on the constrained model considering the user's requirements for Quality of Service (QoS), such as security ranking, focuses on the optimal result in different public key size. It is also introduced that the parameter is optimized when integrating user's requirements for Internet QoS such as the stability of the system and the tolerable response time. Finally, the proposed algorithm is evaluated to be practical and efficient through both analysis and simulation studies.**

***Index Terms*—Quality of Service (QoS), SSL handshake, optimization strategy, security ranking, tolerable response time**

I. INTRODUCTION

SSL protects communications by encrypting messages with a secret key negotiated in the SSL handshake protocol [1]. How to offer some Quality of Service (QoS) that may be satisfied with Web users has become a new issue for study.

SSL protocol allows the server and the client to authenticate each other and to negotiate an encryption algorithm and cryptographic keys before transmitting and receiving the first byte of data [2]. However, such a protocol needs intensive computational resource due to the cost of public-key operations [3]. Many algorithmic approaches for speeding up SSL's performance on a web server are presented in some literatures [4-9]. However, these schemes ignore the satisfactory of the users' requirements for QoS such as the stability of the system and tolerable response time.

Being aware of the computational imbalance between clients and server in the SSL handshake protocol, we proposed a secret exchange algorithm to overcome the problem. The starting point of the proposed scheme is a technique due to batch RSA decryption [10]. This paper adapts the certificate mechanism [11] so as to provide SSL setup with unique certificate issued by Certificate Authority (CA). This paper also proposed the constrained model integrating user-perceived quality into secure Web server design [12, 13]. This paper also optimizes the batch size by the constrained model meeting the user's requirements for quality of service such as security ranking focusing on the optimal result in different public key size. In addition, the proposed scheme in this paper uses the approximate analytical solution of mean response time to optimize the batch size of the server. It is designed for heavily loaded web servers handling many concurrent SSL sessions.

The rest of the paper is organized as follows. Section II describes the secret exchange algorithm in SSL handshake protocol. The proposed constrained model of QoS-aware optimization strategy is presented in Section III. QoS-aware optimization algorithm is presented in Section IV. Section V validates the solutions through both analysis and simulation studies and Section VI concludes the paper.

II. SECRET EXCHANGE ALGORITHM IN SSL HANDSHAKE PROTOCOL

The following Algorithm 1 and Algorithm 2 are secret exchange algorithms of SSL handshake at server end and at client end respectively. When using small public exponent e_1 and e_2, it is possible to decrypt two cipher texts for approximately the price of one [10,11]. This technology facilitates more favorable load distribution by requiring the clients to perform more work (as part of encryption) and the server to perform commensurately less work, thus resulting in better SSL throughput at the server.

Our unique certificate method is to reuse the message *ServerHello.random* in the protocol (see Step 2 of Fig.1)[11]. For simplicity, we only show the related processes and the modified information in the standard SSL handshake protocol.

In the standard SSL protocol, each client encrypts a 48-byte pre-master secret using e_i as the encryption exponents, and the server decrypts the cipher text independently so as to get the *Pre-master secret*. Algorithm 1 obtains the *Pre-master secrets* from multiple clients and hence improves the performance significantly.

Algorithm 1: Secret exchange algorithm at the server end

1. {Given b distinct and pair wise relatively prime public keys $e_1,...,e_b$ all sharing a common modulus $N = pq$, relatively prime to $\phi(N) = (p-1)(q-1)$. n is the bit length of the public modulus N and k the bit length of the bigger of e_i. }

   Construct a full binary tree T_d which is called decryption tree with leaves labeled $e_1,...,e_b$;

   {Each node in the decryption tree mainly need conserve two middle values such as *exponent* and *ciphertext*}.
2. **Construct message** including e_i and the information e_i' about brother's exponent for each client, where $1 \le i \le b$;
3. **upon receiving** the message including cipher text v'_i from each client, where $1 \le i \le b$;
4. {**Compute** two middle values such as *exponent* and *ciphertext* at each **internal nodes** of T_d repeating this computation recursively. The number of external nodes is equal to b-1. The computation phase is to generate the product $v = \prod_{i=1}^{b} v_i^{e/e_i} \bmod N$, where $e = \prod_{i=1}^{b} e_i$. }

   For (i=1 to b-1) {

   $E_L \leftarrow$leftchild.exponent; $E_R \leftarrow$rightchild.exponent;

   Currentnode.exponent $\leftarrow E_L \times E_R$;

   $L \leftarrow$ leftchild.ciphertext; $R \leftarrow$ rightchild.ciphertext;

   Currentnode.ciphertext$\leftarrow L^{E_R} \times R^{E_L}$;}

   $v \leftarrow$rootnode.ciphertext; e $\leftarrow$rootnode.exponent;

   {The value of v and e is simply the result associated with the root}
5. **Compute** $m \leftarrow v^{1/e} \bmod N = \prod_{i=1}^{b} v_i^{1/e_i} \bmod N \quad e \leftarrow \prod_{i=1}^{b} e_i$ {m is the *ciphertext* of root node of T_d.. e is the *exponent* of root node of T_d.}
6. {This Step is to break up the product m to obtain the plaintexts $m_i = v_i^{1/e_i}$ with repeating this computation recursively from the root node. }

   For (i=1 to b-1) {

   Compute X **while** ((X=0 mod E_L) and (X=1 mod E_R)==true);

   $X_L \leftarrow X / E_L$; $X_R \leftarrow (X-1)/E_R$;

   $m_R \leftarrow m^X / (v_L^{X_L} \cdot v_R^{X_R})$; $m_L \leftarrow m / m_R$;}

   {The values of v_L and v_R are simply the results associated with the *ciphertext* of node which have stored at Step 4.}

Figure 1. Secret exchange algorithm 1 at the server end

Algorithm 2: Secret exchange algorithm at the client end

1. **Create** plaintext m_i ($0<m_i<N$); **upon receiving** the message including e_i ;

   Compute $v_i = m_i^{e_i} \bmod N$. $1 \le i \le b$
2. **upon receiving** the message including e_i' which is the brother's exponent value of e_i ;

   Compute $v_i' = v_i^{e_i'} \bmod N$;
3. **Construct** message including v'_i , v_i for server.

Figure 2. Secret exchange algorithm at the client end

III. CONSTRAINED MODEL OF QOS-AWARE OPTIMIZATION STRATEGY

The optimization strategy which is based on the constrained model considering the user's requirements for QoS such as security ranking focuses on the optimal result in different public key sizes.

Lemma 1. Algorithm 1 can generate the b decryption results in $O(\log_2 b(\sum_{i=1}^{b} \log_2 e_i) + \log_2 N)$ modular multiplications and $O(b)$ modular divisions.

Proof: According to Step 5 of Algorithm 1, $m \leftarrow v^{1/e} \bmod N = \prod_{i=1}^{b} v_i^{1/e_i} \bmod N$, with $e = \prod_{i=1}^{b} e_i$, the algorithm can get the result in $O(\log_2 N)$ modular multiplications, which is equivalent to one RSA decryption.

Using the full binary tree as a guide, working from the leaves to the root, for constructing the serial number for every exponent of the leaves, the binary length of the serial number is equal to $\lfloor \log_2 b \rfloor$. In other words, the depth of the leaves is equal to $\lfloor \log_2 b \rfloor$.

According to Step 6 of Algorithm 1, the algorithm takes the recursive result from left child and right child, and the result associated with this node is $m_R \leftarrow m^X / (v_L^{X_L} \cdot v_R^{X_R})$. The computation phase is to break up the product m to obtain the plaintexts $m_i = v_i^{1/e_i}$, which we wish to decrypt simultaneously.

Note that v_l and v_r have already been computed and storied, as the left and right branch values of the root, during the tree based computation of m at Step 4 of Algorithm 1. By definition X is the unique solution ((X=0 mod E_L) and (X=1 mod E_R)= =true), Note that $\log_2 X < \log_2 e$ and $X_L \leftarrow X / E_L$; $X_R \leftarrow (X-1)/E_R$, we can get $\log_2 X_L + \log_2 X_R < \log_2 X < \log_2 e$ with $e = \prod_{i=1}^{b} e_i$ [10].

Because the depth of the leaves is equal to $\lfloor \log_2 b \rfloor$, for every plaintext result $m_i = v_i^{1/e_i}$, every node contributes at most $\lfloor \log_2 b \rfloor$ bits to the appropriate exponents the computation of m^X , $v_L^{X_L}$ and $v_R^{X_R}$ recursive result.

Because the binary length of exponent e_i is $\lfloor \log_2 e_i \rfloor$, Step 6 of Algorithm 1 can generate the following b results in $O(\log_2 b(\sum_{i=1}^{b} \log_2 e_i)$ modular multiplications or $o(\log_2 b \log_2 e)$ modular multiplications with $e = \prod_{i=1}^{b} e_i$.

To solve for $m_R \leftarrow m^X / (v_L^{X_L} \cdot v_R^{X_R})$, we divide $v_L^{X_L} \cdot v_R^{X_R}$ by m^X , the number of modular divisions required is $O(b)$.

At all, Algorithm 1 can generate the b results

$m_1^{1/e_1} (\bmod N)$, $m_2^{1/e_2} (\bmod N)$, $\ldots m_b^{1/e_b} (\bmod N)$

in $O(\log_2 b(\sum_{i=1}^{b}\log_2 e_i)+\log_2 N)$ modular multiplications and $O(b)$ modular divisions.

Then Lemma 1 is proved.

Lemma 2. Choosing the batch size b, which satisfied $2 \le b \le \frac{n}{(\log_2 n)^2}$, and choosing the e_i exponents to be polynomial in n, we get $O((\log_2 n)^2+n)$ modular multiplications and $O(\frac{n}{(\log_2 n)^2})$ modular divisions. n is defined as the binary length of modules N.

Proof: We can easily get $\log_2 N=n$, where n is defined as the binary length of modules N.

We can easily get $\frac{n}{(\log_2 n)^2} < n$, because n is a negative number.

Also because the function $\log_2 x$ increases with x, we can get $\log_2 \frac{n}{(\log_2 n)^2} < \log_2 n$. Because of choosing the batch size b which satisfies $2 \le b \le \frac{n}{(\log_2 n)^2}$, we can derive

$\log_2 b \le \log_2 \frac{n}{(\log_2 n)^2}$ and

$\log_2 b(\sum_{i=1}^{b}\log_2 e_i)+\log_2 N) \le \log_2 \frac{n}{(\log_2 n)^2}(\sum_{i=1}^{b}\log_2 e_i)+\log_2 N)$

Due to Lemma 1, where $\sum_{i=1}^{b}\log_2 e_i = \log_2 e$ and $\log_2 N=n$, it can be described as

$$O(\log_2 \frac{n}{(\log_2 n)^2}(\sum_{i=1}^{b}\log_2 e_i)+\log_2 N) < O(\log_2 e(\log_2 n)+n)$$

By choosing the e_i exponents to be polynomial in n,

Thus $e<n$, the following equation is derived as

$$O(\log_2 e(\log_2 n)+n) < O((\log_2 n)^2+n)$$

Then Lemma 2 is proved.

Constrained model considering the user's requirements for QoS such as security ranking focuses is proposed based on Lemma 2. We optimize the batch size b for a specific modulus size, and obtain better results for smaller batches if the modulus is relatively small. According to Lemma 2, the batch size is optimized as $\frac{n}{(\log_2 n)^2}$ in this constrained model.

IV. QOS-AWARE OPTIMIZATION ALGORITHM

Let the decryption time of Algorithm 1 in SSL handshake time be T_b. The decryption time in SSL handshake T_b can be estimated as the following [11].

$$(\frac{3n^3+n^2(44b+3b^3-1)}{b(3n^3+n^2)})bT_{rsa} = (\frac{3n+(44b+3b^3k-1)}{b(3n+1)})bT_{rsa} \quad (1)$$

Since T_b is the majority of the service time, the batching service time of the server τ is T_b roughly.

Lemma 3. To satisfy the client's requirement for the stability of the system, the decryption time in SSL handshake T_b is less than the batch size multiplied by the mean Poisson distributed arrival time interval when the time in the Batch Queue Model M/D/1, thus

$$\tau \approx T_b < b/\lambda \quad (2)$$

Proof. Let X_i (i=1,2, ...) be the arrival time interval of two consecutive requests, and Y be the time interval of b consecutive requests. Batch Queue Model M/D/1 has been described in our previous work [11].

If the system achieves the stability when the time $t \to \infty$ for M/D/1 queue model, $T_b < E(Y)$, where $E(Y)$ is the expected value of Y. Because the X_i is a random variable with independent identical distribution, the average arrival time interval of b consecutive requests is

$$E(Y) = E(\sum_{i=1}^{b} X_i) = bE(X_i) = b/\lambda \quad (3)$$

Then Lemma 3 is proved.

Lemma 4. In the Batch Queue Model M/D/1, to satisfy the client's requirement for the stability of the system, thus $T_q < b/2\lambda$

Proof. In the Batch Queue Model M/D/1, the value of T_q is derived following the equation

$$T_q = (\frac{1-e^{-\lambda\tau}}{1-e^{-\lambda\tau}+e^{-1.5\lambda\tau}})T_r$$
$$= (\frac{e^{\lambda\tau}-1}{e^{-\lambda\tau}-1+e^{-0.5\lambda\tau}})T_r = (\frac{1}{1+\frac{1}{(e^{\lambda\tau}-1)e^{0.5\lambda\tau}}})T_r \quad (4)$$

Where $T_r = 0.5\tau$, due to Lemma 3, it can be easily described as

$$T_q = (\frac{0.5\tau}{1+\frac{1}{(e^{\lambda\tau}-1)e^{0.5\lambda\tau}}}) < (\frac{1}{1+\frac{1}{(e^{b}-1)e^{0.5b}}})(\frac{b}{2\lambda}) \quad (5)$$

It can be easily described as when $b \le 2$,

$$0.944 \approx 1+\frac{1}{(e^2-1)e^{0.5\times 2}} \le 1+\frac{1}{(e^b-1)e^{0.5b}} < 1 \quad (6)$$

. Then the value bound of the upper limit of T_q is estimated as [0.944 $b/2\lambda$, $b/2\lambda$]. Then Lemma 4 is proved. Tolerable response time (TRT) is defined as the delay time a client can tolerate between a request for a secure web page and receiving the page [12-14]. The real response time (RRT) is the interval between the receipt of the end of transmission of an SSL-based inquiry message and the beginning of the transmission of a response message to the station originating the SSL handshake.

Lemma 5. In the Batch Queue Model M/D/1, to satisfy the client's requirement for the tolerable response time, *RRT*<*TRT* , thus,

$$\Rightarrow b < 0.4(\lambda \times TRT + 1)$$

Proof. The mean real response time (*RRT*) is denoted as the sum of T_q, T_c and the T_b.

In the Batch Queue Model M/D/1, the value bound of the upper limit of T_q is estimated as $b/2\lambda$ derived from Lemma 4 (refer to Eq. 6).

The value bound of the upper limit of T_b is estimated as b/λ derived from Lemma 3 (refer to Eq. 2).

T_c is the mean time for waiting other client in the same batching which is easily derived that the max value of T_c is $(b-1)/\lambda$.

On the other hand, it is supposed that the solution of *b* should satisfy the approximate bound, which is derived from Lemma 3, Lemma 4 and described as the following equation:

$$RRT = T_q + T_c + T_b < \frac{b}{2\lambda} + \frac{(b-1)}{\lambda} + \frac{b}{\lambda} < TRT \quad (7)$$

$$\Rightarrow b < 0.4(\lambda \times TRT + 1)$$

Then Lemma 5 is proved.

Algorithm 3: QoS-aware optimization algorithm
Input:, λ , *TRT*, *PKS*
Output: *Optimal_b*, T_b, T_b_real, *Speedup, Speedup_real*
1.Compute the initial value of *b*
initial_b $\leftarrow$ int(0.4($\lambda \times TRT$ +1)); (refer to Eq. 7)
2.*n* $\leftarrow$ *PKS*; *estimate_b* $\leftarrow \left\lfloor \frac{n}{(\log_2 n)^2} \right\rfloor$
3.If (*estimate_b*< *initial_b*)
Then { *initial_b* $\leftarrow$ *estimate_b* ; }
Successfind $\leftarrow$ false;
4.If (*initial_b*<=1) then do conventional_RSA_decryption( ); return;
5. *b* $\leftarrow$ *initial_b*;
6. While (*b*!=1)
do { $T_b = (\frac{3n + (44b + 3b^3k - 1)}{b(3n+1)}) bT_{rsa}$ (refer to Eq. 1)
If ($T_b \le b/\lambda$) then { (refer to Eq. 2)
Optimal_b $\leftarrow$ *b*; Successfind $\leftarrow$ true; break; }
Elseif ($T_b > b/\lambda$) then { *b* $\leftarrow$ *b*-1;}
}/* While (*b*!=1)*/
7. If (initial_b<=1) then conventional_RSA_decryption( ); return;
8. **Compute** T_b_real ;
Speedup $\leftarrow \frac{b(3n+1)}{3n + (44b + 3b^3k - 1)}$; (refer to Eq. 1)
9. **Compute** *Speedup_real* $\leftarrow$ Trsa / T_b_real;

Figure 3. QoS-aware optimization algorithm

Combining the user's requirements for QoS such as security ranking, the stability of the system and tolerable response time, these strategies aim to optimize the parameter *b*, which means the size of multi-clients for aggregate decryption in Algorithm 1. QoS-aware optimization algorithm is described in Fig. 4, which satisfies these strategies in this paper.

According to Lemma 5, the initial value of *b* is estimated at Step 1 of Algorithm 3 with *TRT* and λ as input values. According to Lemma 2, *b* is estimated at Step 2 with *PKS* as input value. If condition of optimal batch can not be satisfied, the algorithm has the ability to fall back on conventional_RSA_decryption () which means the decryption with plain RSA, which is described at Step 4 and Step 7. The computation of T_b is performed using Eq. 1 at Step 6. Step 6 sorts *b* to satisfy max solution of $T_b < b/\lambda$ according to Lemma 3 in descending order from the upper limit computing at Step 3 to two.

V. VALIDATION OF ANALYTICAL MODELS AND PERFORMANCE EVALUATION STUDY

A. *Validation of analytical models*

The analytical results and simulative results are executed on a machine with a Dell Intel Pentium IV processor clocked at 3.20GHz and 1GMB RAM. Specifically, this paper performs the simulation of SSL handshake secret exchange algorithm with very small public exponents, namely *e*=3, 5, 7, 11, 13, 17, etc. It is assumed that the value (*TRT*) is equal to 1 second and 8 seconds as examples both in the analytical model and simulation. It is assumed that the value public key size (*PKS*) is equal to 512, 1024 and 2048 bits length as examples both in the analytical model and simulation.

Table 1 validates the result of *Optimal_b* described by the constrained model of QoS-aware optimization strategy. It is assumed that the *TRT* is equal to 1s in analytical model and simulation. As small arrival rates, *b* is almost uniformly calculated by our analytical model (Table 1). Since arrival rates are small (i.e., λ<2), there is very little opportunity to batch, and therefore, the solution of *b* is relatively small (Table 1). Even at higher arrival rate, the analytical result and simulation result are very close. The solution of the optimal batch size is increased with λ both in analytic and simulation when λ<30 (i.e., *PKS*=1024bits) approximately. Otherwise, the *RRT* is not increased obviously. The solution of *b* is decreased with λ when λ>60 (i.e., *PKS*=1024bits) approximately. The solution of *b* can not satisfy the user's requirements for the stability of the system, in other words, the solution of *b* can not satisfy $T_b \le b/\lambda$ according to Lemma 3 when λ>37.5 approximately (i.e., *PKS*=2048bits).

Table 1 Optimal batch size in constrained model validation

λ/*PKS*	*Optimal_b*					
	analytical model			simulation results		
	512	1024	2048	512	1024	2048
1	-	-	-	-	-	-
2	2	2	2	2	2	2
3	2	2	2	2	2	2
4	3	3	3	3	3	3
5	4	4	4	4	4	4
10	8	8	6	8	8	6
20	8	10	6	8	10	6
30	8	10	6	8	10	6
40	8	10	-	8	10	-
50	8	10	-	8	10	-
60	8	6	-	8	6	-
70	8	6	-	8	6	-
80	8	6	-	8	6	-
90	6	5	-	6	5	-
100	6	5	-	6	5	-

But with non-batching system, it becomes unstable when $\lambda > 1/T_{rsa} = 1/0.16 = 6.25$ for 2048 bits keys due to the fact that a non-batching system becomes unstable when $\lambda > \tau$.

B. Performance evaluation

The simulation result of the RSA decryption time T_{rsa} with larger public exponent, namely e=65537 is about 16 ms, 32ms and 130ms with public modulus N is 512 bits length, 1024 bits length, and 2048 bits length respectively, which is tested using reiterative results.

The multi-factor RSA [9] can expect the theoretical speedup of around 2.25 with $n = pqr$ and 3.38 for $n = p^2q$. Experiments show the real speedup to be around 1.73 and 2.3, respectively. Rebalanced RSA offers the theoretical speedup of 3.6 but the actual speedup is 3.2 for 1024bits keys. Specifically, d is chosen to be close to n such that both d mod (p-1) and d mod (q-1) are small integers [9]. The resulting public exponent e also becomes close to n, which is much larger than typical values (i.e., e = 3, 17, or 65537). It is in fact so large that Microsoft Internet Explorer (IE) cannot accept it; SB (Shacham and Boneh) scheme [7] offers the speedup factor of 2.5 for 1024bits keys. The downside is obvious because that CA's charge per certificate regardless of whether the certificate is for the same site or not. It also ignores the satisfaction of the user's requirements for QoS, where the batch size is equal to four.

Table 2 Speedup of decryption time validation

b/*PKS*	Speedup of decryption time (*ms*)					
	Speedup			*Speedup_real*		
S	512	1024	2048	512	1024	2048
2	1.81	1.90	1.95	1.78	1.83	1.90
4	3.68	3.05	3.42	3.21	2.93	3.39
6	2.10	2.80	3.82	2.01	2.76	3.80
8	1.28	2.18	3.47	1.14	2.09	3.39

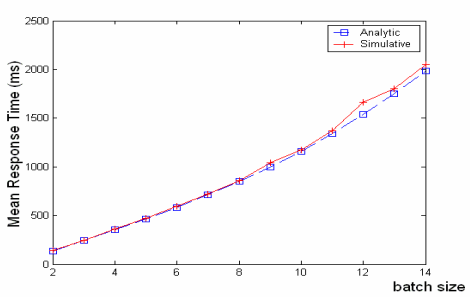
Our algorithm offers the speedup factor of 2.76 (Table 2) for 1024bits key which is used in SSL handshake protocol frequently. Typically, b is equal to 6 for optimal performance when 60< λ <80 approximately (Table 1). Obviously, our scheme not only achieves better speedup factor and overcomes these disadvantages of the previous schemes. All the methods are backward compatible with standard RSA. Also, all speedup discussed is based on 1024-bit RSA and is relative to the cost of performing plain RSA decryptions.

It is assumed that *TRT* is equal to 8 seconds in Figure 4. These figures show that *RRT* is almost linear when λ is relatively small. This is due to the fact that $RRT = T_q + T_c + T_b$ (refer to Eq. 7). When λ is relatively small, the main contribution to *RRT* is made by T_c (i.e., λ = 10, *PKS*=1024bits). It is evident that the time T_c is increased linearly with b. T_b is also increased with b. Therefore, *RRT* is also increased with b when λ is relatively large (i.e. λ= 80, *PKS*=1024bits).

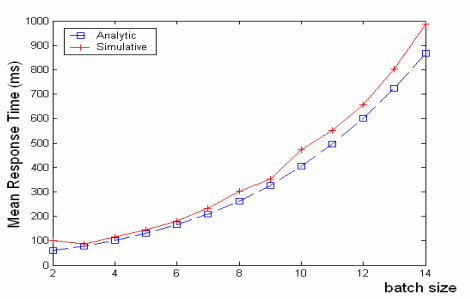
A non-batching system becomes unstable when $\lambda > 1/T_{rsa} = 1/0.032 = 31.25$ for 1024bits keys. When the non-batching system is stable, the mean response time T' can be estimated as Eq. 8 [11]. The mean service time τ' is deterministic in the non-batching in M/D/1 queue model. Since T_{rsa} is the majority of the service time, the mean service time τ' of the server is roughly T_{rsa}. .

$$T' = \tau' + \tau' \left(\frac{\tau'\lambda}{2(1-\tau'\lambda)}\right) \approx T_{rsa} + T_{rsa}\left(\frac{T_{rsa}\lambda}{2(1-T_{rsa}\lambda)}\right) \quad (8)$$

Fig. 5 (i.e. *TRT* = 8) illustrates the comparison of the mean response time of our scheme with non-batching. The vertical axis in each graph is the mean response time over the batch size divided by the mean response time with non-batching. The optimal batch size in our scheme is equal to 10 when λ=30. The speedup of the mean response time is an optimal one that equals to 6.32 approximately. It is clear that with the optimal batch size our scheme has considerable advantages and while costs little.



(a) λ= 10



(b) λ= 80

Figure 4. Mean response time validation over batch size

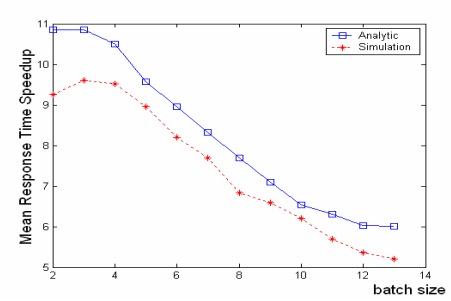


Figure 5. Mean response time speedup

VI. CONCLUSION

In conclusion, this paper proposes the secret exchange algorithm in SSL handshake protocol. Combining the user's requirements for Quality of Service (QoS) such as security ranking, the stability of the system, and the tolerable response time, these strategies aim to optimize the parameter *b* which means the size of multi-clients for aggregate decryption. The parameter optimization-based SSL handshake is a viable option for secure communications. Currently we mainly investigated this work based on the Internet with high speed client/server computing paradigm. As our future work, we plan to extend it to more scenarios including P2P networks and wireless networks.

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REFERENCES

[1] I. Goldberg, and D. Wagner, "Randomness and the Netscape Browser", *Dr. Dobb's Journal*, January 1996, pp. 66-70.

[2] A. O. Freier, P. Karlton, P. C. Kocher, "The SSL ProtocolV3.0", 1996-11-01.

[3] T. S. Sobh, A. Elgohary, M. Zaki, "Performance Improvements on the Network Security Protocols", International Journal of Network Security, Vol.6, No.1, 2008, pp.103–115.

[4] H.M.Sun, C.T. Yang, M. E. Wu, "Short-Exponent RSA", IEICE Transactions on Fundamentals of Electronics, Communications and Computer Sciences, Vol.E92-A, No.3, 2009, 3, pp.912-918.

[5] F.C. Kuo, H. Tschofenig, F. Meyer, et.al, "Comparison Studies between Pre-shared and Public Key Exchange Mechanisms for Transport Layer Security", Proceedings of IEEE Global Internet Symposium 2006, Spain, April 2006, pp.1-6.

[6] C. Castelluccia, E. Mykletun, and G.Tsudik, "Improving Secure Server Performance by Re-balancing SSL/TLS Handshakes", Proceedings of the 2006 ACM Symposium on Information, computer and communications security. New York, NY, USA: ACM Press, 2006, pp.26-34

[7] H. Shacham, and D. Boneh, "Improving SSL Handshake Performance via Batching," RSA'2001, Lecture Notes in Computer Science, San Francisco, CA, USA: Spring Verlag, Vol. 2020, 2001, pp.28-43.

[8] T. Takagi, "Fast RSA-Type Cryptosystems Using N-adic Expansion", Proceedings of Crypto '97, Lecture Notes in Computer Science, Berlin, Germany: Spring-Verlag, 1997, vol.1294, pp.372-384.

[9] D. Boneh, H. Shacham, "Fast Variants of RSA", RSA Laboratories Cryptobytes, 2002, 5 (1), pp.1-8.

[10] A. Fiat, "Batch RSA," Crypto'89, pp.175-185, 1989. See also Journal of Cryptology, 1997,10 (2), pp.75-88.

[11] F. Qi, W. Jia, F. Bao, et.al, "Batching SSL/TLS Handshake Improved", Lecture Notes in Computer Science, Berlin, Germany: Spring-Verlag, 2005, Vol 3783, pp. 402-410.

[12] N. Bhatti, A. Bouch, A. Kuchinsky, "Integrating User-perceived Quality into Web Server Design", Proceedings of the 9th International World Wide Web Conference, Amsterdam, Netherlands,2000, pp.24-334.

[13] A. Bouch, A. Kuchinsky, N. Bhatti, "Quality is in the Eye of the Beholder: Meeting User's Requirements for Internet Quality of Service", Proceedings of the CHI 2000 Conference on Human Factors in Computing Systems, The Hague, The Netherlands,2000,pp.297-304.

[14] F. Nah, "Study on Tolerable Waiting Time: How Long Are Web Users Willing to Wait?" Behaviour & Information Technology, 2004, Vol23, pp.153-163.