Q2.1 Internet work security is both fascinating and complex. Please specify some of the reasons.

Ans:

1. Security involving communications and networks is not as simple as it might first appear to the novice. The requirements seem to be straightforward; indeed, most of the major requirements for security services can be given self-explanatory one-word labels: confidentiality, authentication, nonrepudiation, integrity. But the mechanisms used to meet those requirements can be quite complex, and understanding them may involve rather subtle reasoning.

2. In developing a particular security mechanism or algorithm, one must always consider potential attacks on those security features. In many cases, successful attacks are designed by looking at the problem in a completely different way, therefore exploiting an unexpected weakness in the mechanism.

3. Because of point 2, the procedures used to provide particular services are often counterintuitive: It is not obvious from the statement of a particular requirement that such elaborate measures are needed. It is only when the various countermeasures are considered that the measures used make sense.

4. Having designed various security mechanisms, it is necessary to decide where to use them. This is true both in terms of physical placement (e.g., at what points in a network are certain security mechanisms needed) and in a logical sense [e.g., at what layer or layers of an architecture such as TCP/IP (Transmission Control Protocol/Internet Protocol) should mechanisms be placed].

5. Security mechanisms usually involve more than a particular algorithm or protocol. They usually also require that participants be in possession of some secret information (e.g., an encryption key), which raises questions about the creation, distribution, and protection of that secret information. There is also a reliance on communications protocols whose behavior may complicate the task of developing the security mechanism. For example, if the proper functioning of the security mechanism requires setting time limits on the transit time of a message from sender to receiver, then any protocol or network that introduces variable, unpredictable delays may render such time limits meaningless.

© IETE

Q2.2 Please write the pseudocode for Millar-Rabin test.

Ans:

```
Miller_Rabin_Test (n, a)                    // n is the number; a is the base.
{
    Find m and k such that n − 1 = m × 2^k
    T ← a^m mod n
    if (T = ± 1)  return "a prime"
    for (i ← 1 to k − 1)                    // k − 1 is the maximum number of steps.
    {
        T ← T^2 mod n
        if (T = +1) return "a composite"
        if (T = −1) return "a prime"
    }
    return "a composite"
}
```

Q3.1 Describe the procedure for encrypting and decrypting a message through Enigma machine

Ans:

Procedure for Encrypting a Message

To encrypt a message, the operator followed these steps:

1. Set the starting position of the rotors to the code of the day. For example, if the code was "HUA", the rotors were initialized to "H", "U", and "A", respectively.
2. Choose a random three-letter code, such as "ACF". Encrypt the text "ACFACF" (repeated code) using the initial setting of rotors in step 1. For example, assume the encrypted code is "OPNABT".
3. Set the starting positions of the rotors to OPN (half of the encrypted code).
4. Append the encrypted six letters obtained from step 2 ("OPNABT") to the beginning of the message.
5. Encrypt the message including the 6-letter code. Send the encrypted message.

Procedure for Decrypting a Message

To decrypt a message, the operator followed these steps:

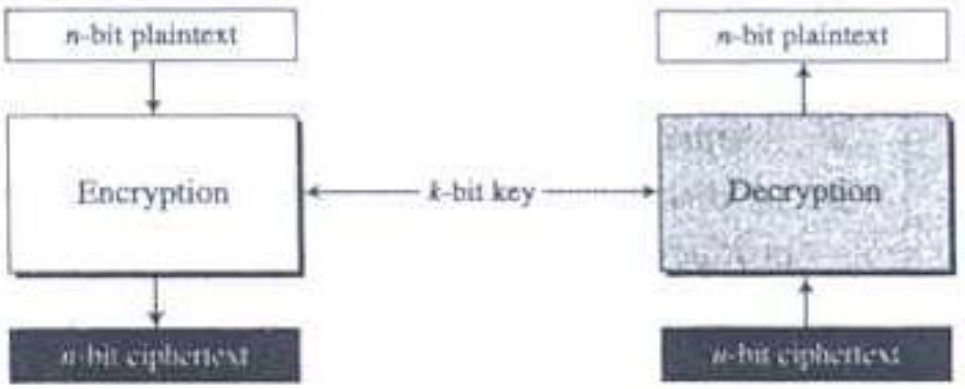
1. Receive the message and separate the first six letters.
2. Set the starting position of the rotors to the code of the day.
3. Decrypt the first six letters using the initial setting in step 2.
4. Set the positions of the rotors to the first half of the decrypted code.
5. Decrypt the message (without the first six letters).

Q3.2 What is block cipher?

Ans: A block cipher is an encryption/decryption scheme in which a block of plaintext is treated as a whole and used to produce a ciphertext block of equal length. Many block ciphers have a Feistel structure. Such a structure consists of a number of identical rounds of processing. In each round, a substitution is performed on one half of the data being processed, followed by a permutation that interchanges the two halves. The original key is expanded so that a different key is used for each round.

Q3.3 Please draw the diagram for a modern block cipher

Ans: The diagram for a modern block cipher:



Q4.1 How key size and nature of algorithm affect the security provided by DES.

Ans:

Yes, there have been some concerns in DES. These concerns, by and large, fall into two areas: key size and the nature of the algorithm.

The Use of 56-Bit Keys

With a key length of 56 bits, there are 2 possible keys, which is approximately 7.2 x 10. Thus, on the face of it, a brute-force attack appears impractical. Assuming that, on average, half the key space has to be searched, a single machine performing one DES encryption per microsecond would take more than a thousand years to break the cipher.

However, the assumption of one encryption per microsecond is overly conservative. As far back as 1977, Diffie and Hellman postulated that the technology existed to build a parallel machine with 1 million encryption devices, each of which could perform one encryption per microsecond. This would bring the average search time down to about 10 hours. DES finally and definitively proved insecure in July 1998, when the Electronic Frontier Foundation (EFF)

announced that it had broken a DES encryption using a special-purpose "DES cracker" machine that was built for less than $250,000. The attack took less than three days. The EFF has published a detailed description of the machine, enabling others to build their own cracker. And, of course, hardware prices will continue to drop as speeds increase, making DES virtually worthless.

It is important to note that there is more to a key-search attack than simply running through all possible keys. Unless known plaintext is provided, the analyst must be able to recognize plaintext as plaintext. If the message is just plain text in English, then the result pops out easily, although the task of recognizing English would have to be automated. If the text message has been compressed before encryption, then recognition is more difficult. And if the message is some more general type of data, such as a numerical file, and this has been compressed, the problem becomes even more difficult to automate. Thus, to supplement the brute-force approach, some degree of knowledge about the expected plaintext is needed, and some means of automatically distinguishing plaintext from garble is also needed. The EFF approach addresses this issue as well and introduces some automated techniques that would be effective in many contexts. Fortunately, there are a number of alternatives to DES, the most important of which are AES and triple DES.

The Nature of the DES Algorithm

Another concern is the possibility that cryptanalysis is possible by exploiting the characteristics of the DES algorithm. The focus of concern has been on the eight substitution tables, or S-boxes, that are used in each iteration. Because the design criteria for these boxes, and indeed for the entire algorithm, were not made public, there is a suspicion that the boxes were constructed in such a way that cryptanalysis is possible for an opponent who knows the weaknesses in the S-boxes. This assertion is tantalizing, and over the years a number of regularities and unexpected behaviors of the S-boxes have been discovered. Despite this, no one has so far succeeded in discovering the supposed fatal weaknesses in the S-boxes.

Q4.2 Provide a brief overview of differential cryptanalysis.

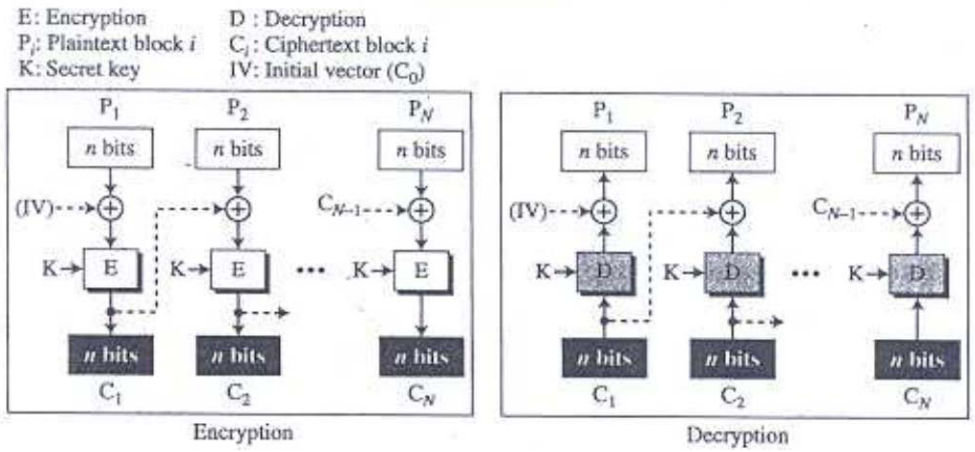
Ans: Differential Cryptanalysis

One of the most significant advances in cryptanalysis in recent years is differential cryptanalysis. Differential cryptanalysis was not reported in the open literature until 1990. The first published effort appears to have been the cryptanalysis of a block cipher called FEAL by Murphy. This was followed by a number of papers by Biham and Shamir, who demonstrated this form of attack on a variety of encryption algorithms and hash functions.

The most publicized results for this approach have been those that have application to DES. Differential cryptanalysis is the first published attack that is capable of breaking DES in less than 2 complexity. The scheme can successfully cryptanalyze. DES with an effort on the order of 2 encryptions, requiring 2 chosen plaintexts. Although 2 is certainly significantly less than 2 the need for the adversary to find 2 chosen plaintexts makes this attack of only theoretical interest. Although differential cryptanalysis is a powerful tool, it does not do very well against DES. The reason, according to a member of the IBM team that designed DES, is that differential cryptanalysis was known to the team as early as 1974. The need to strengthen DES against attacks using differential cryptanalysis played a large part in the design of the S-boxes and the permutation P. Differential cryptanalysis of an eight-round LUCIFER algorithm requires only 256 chosen plaintexts, whereas an attack on an eight-round version of DES requires 2 chosen plaintexts.

Q5.1 Please draw a diagram depicting a Cipher Block Chaining (CBC) mode.

Ans:



Q5.2 What are the advantages of Asymmetric Encryption.

Ans:

Asymmetric encryption is a form of cryptosystem in which encryption and decryption are performed using a public key and one a private key. It is also known as public-key encryption. Asymmetric encryption transforms plaintext into ciphertext using a one of two keys and an encryption algorithm. Using the paired key and a decryption algorithm, the plaintext is recovered from the ciphertext. Asymmetric encryption can be used for confidentiality, authentication, or both. The most widely used public-key cryptosystem is RSA. The difficulty of attacking RSA is based on the difficulty of finding the prime factors of a composite number. The development of public-key cryptography is the greatest

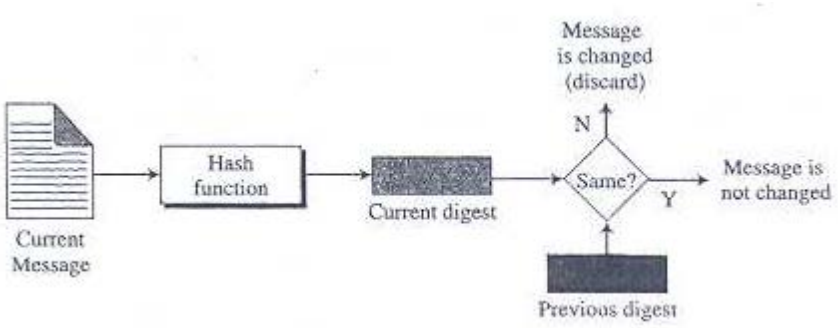
and perhaps the only true revolution in the entire history of cryptography. From its earliest beginnings to modern times, virtually all cryptographic systems have been based on the elementary tools of substitution and permutation. After millennia of working with algorithms that could essentially be calculated by hand, a major advance in symmetric cryptography occurred with the development of the rotor encryption/decryption machine. The electromechanical rotor enabled the development of fiendishly complex cipher systems. With the availability of computers, even more complex systems were devised, the most prominent of which was the Lucifer effort at IBM that culminated in the Data Encryption Standard (DES). But both rotor machines and DES, although representing significant advances, still relied on the bread-and-butter tools of substitution and permutation.

Public-key cryptography provides a radical departure from all that has gone before. For one thing, public-key algorithms are based on mathematical functions rather than on substitution and permutation. More important, public-key cryptography is asymmetric, involving the use of two separate keys, in contrast to symmetric encryption, which uses only one key. The use of two keys has profound consequences in the areas of confidentiality, key distribution, and authentication.

Q6.1 How do we check the integrity of a message? Explain using a diagram.

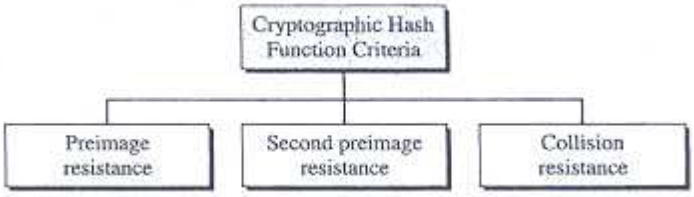
Ans:

To check the integrity of a message, or document, we run the cryptography hash function again and compare the new message digest with the previous one. If both are the same, we are sure that the original message has not been changed. The diagram below shows the idea**.**



Q6.2 What are the three criteria, which needs to be satisfied by a cryptographic hash function?

Ans: A cryptographic hash function must satisfy three criteria: preimage resistance, second preimage resistance, and collision resistance, as shown below:



Q6.3 What is SHA?

Ans: The Secure Hash Algorithm (SHA) was developed by the National Institute of Standards and Technology (NIST) and published as a federal information processing standard (FIPS 180) in 1993; a revised version was issued as FIPS 180-1 in 1995 and is generally referred to as SHA-1. The actual standards document is entitled Secure Hash Standard. SHA is based on the hash function MD4 and its design closely models MD4. SHA-1 is also specified in RFC 3174, which essentially duplicates the material in FIPS 180-1, but adds a C code implementation.

SHA-1 produces a hash value of 160 bits. In 2002, NIST produced a revised version of the standard, FIPS 180-2, that defined three new versions of SHA, with hash value lengths of 256, 384, and 512 bits, known as SHA-256, SHA-384, and SHA-512. These new versions have the same underlying structure and use the same types of modular arithmetic and logical binary operations as SHA-1. In 2005, NIST announced the intention to phase out approval of SHA-1 and move to a reliance on the other SHA versions by 2010. Shortly thereafter, a research team described an attack in which two separate messages could be found that deliver the same SHA-1 hash using 2 operations, far fewer than the 2 operations previously thought needed to find a collision with an SHA-1 hash. This result should hasten the transition to the other versions of SHA**.**

Q6.4 In SHA-512, what is the minimum and maximum number of padding bits that can be added to a message?

Ans:

a. The minimum length of padding is 0 and it happens when $(-M - 128) \bmod 1024$ is 0. This means that $|M| = -128 \bmod 1024 = 896 \bmod 1024$ bits. In other words, the last block in the original message is 896 bits. We add a 128-bit length field to make the block complete.

b. The maximum length of padding is 1023 and it happens when $(-|M| - 128) = 1023 \bmod 1024$. This means that the length of the original message is $|M| = (-128 - 1023) \bmod 1024$ or the length is $|M| = 897 \bmod 1024$. In this case, we cannot just add the length field because the length of the last block exceeds one bit more than 1024. So we need to add 897 bits to complete this block and create a second block of 896 bits. Now the length can be added to make this block complete.

Q7.1 What is the need for Digital Signatures? What are the properties and requirements for a digital signature?

Ans: Message authentication protects two parties who exchange messages from any third party. However, it does not protect the two parties against each other. Several forms of dispute between the two are possible.

For example, suppose that John sends an authenticated message to Mary. Consider the following disputes that could arise:

1. Mary may forge a different message and claim that it came from John. Mary would simply have to create a message and append an authentication code using the key that John and Mary share.
2. John can deny sending the message. Because it is possible for Mary to forge a message, there is no way to prove that John did in fact send the message. Both scenarios are of legitimate concern. Here is an example of the first scenario: An electronic funds transfer takes place, and the receiver increases the amount of funds transferred and claims that the larger amount had arrived from the sender. An example of the second scenario is that an electronic mail message contains instructions to a stockbroker for a transaction that subsequently turns out badly. The sender pretends that the message was never sent.

In situations where there is not complete trust between sender and receiver, something more than authentication is needed. The most attractive solution to this problem is the digital signature. The digital signature is analogous to the handwritten signature. It must have the following properties:

- It must verify the author and the date and time of the signature.
- It must to authenticate the contents at the time of the signature.
- It must be verifiable by third parties, to resolve disputes.
- Thus, the digital signature function includes the authentication function.

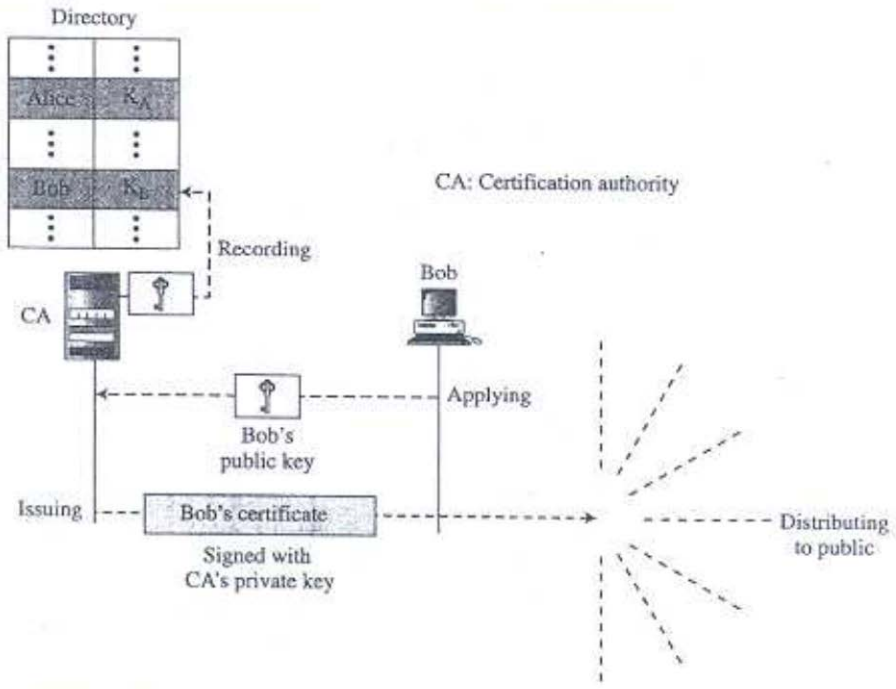
On the basis of these properties, we can formulate the following requirements for a digital signature:

- The signature must be a bit pattern that depends on the message being signed.
- The signature must use some information unique to the sender, to prevent both forgery and denial.
- It must be relatively easy to produce the digital signature.
- It must be relatively easy to recognize and verify the digital signature.
- It must be computationally infeasible to forge a digital signature, either by constructing a new message for an existing digital signature or by constructing a fraudulent digital signature for a given message.

It must be practical to retain a copy of the digital signature in storage.

Q7.2 Please draw a diagram depicting the concept of CA.

Ans:



Q8.1 Describe the reasons for popularity and growth of PGP.

Ans: PGP has grown explosively and is now widely used. A number of reasons can be cited for this growth:

1.It is available free worldwide in versions that run on a variety of platforms, including Windows, UNIX, Macintosh, and many more. In addition, the commercial version satisfies users who want a product that comes with vendor support.

2. It is based on algorithms that have survived extensive public review and are considered extremely secure. Specifically, the package includes RSA, DSS, and Diffie-Hellman for public-key encryption; CAST-128, IDEA, and 3DES for symmetric encryption; and SHA-1 for hash coding.

3. It has a wide range of applicability, from corporations that wish to select and enforce a standardized scheme for encrypting files and messages to individuals who wish to communicate securely with others worldwide over the Internet and other networks.

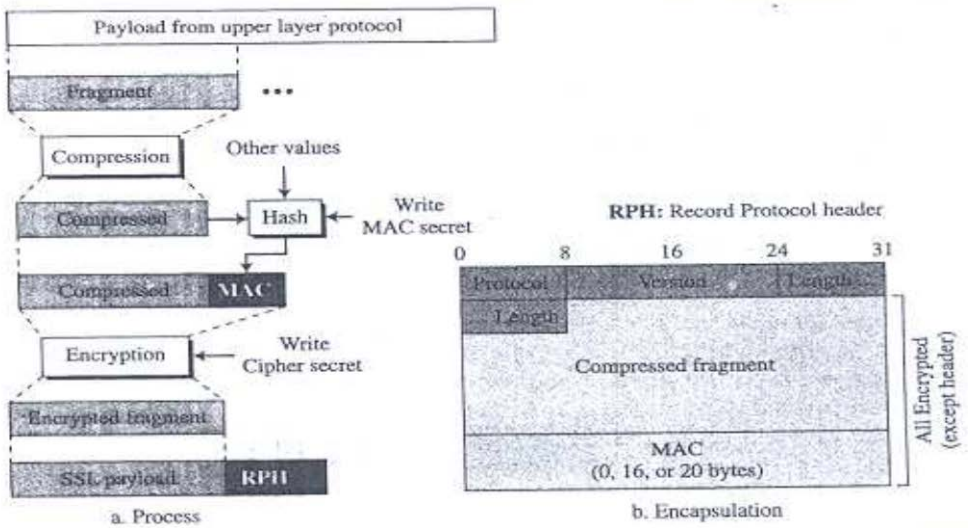
4. It was not developed by, nor is it controlled by, any governmental or standards organization. For those with an instinctive distrust of "the establishment," this makes PGP attractive.

5. PGP is now on an Internet standards track (RFC 3156). Nevertheless, PGP still has an aura of an antiestablishment endeavor.

Q8.2 What are the data types and subtypes in MIME?
Ans:

Type	*Subtype*	*Description*
	Plain	Unformatted.
	HTML	HTML format.
Multipart	Mixed	Body contains ordered parts of different data types.
	Parallel	Same as above, but no order.
	Digest	Similar to Mixed, but the default is message/RFC822.
	Alternative	Parts are different versions of the same message.
Message	RFC822	Body is an encapsulated message.
	Partial	Body is a fragment of a bigger message.
	External-Body	Body is a reference to another message.
Image	JPEG	Image is in JPEG format.
	GIF	Image is in GIF format.
Video	MPEG	Video is in MPEG format.
Audio	Basic	Single channel encoding of voice at 8 KHz.
Application	PostScript	Adobe PostScript.
	Octet-stream	General binary data (eight-bit bytes).

Q9.1 Please draw a diagram depicting the processing done by the record protocol.
Ans:



Q9.2 What are the differences between the cipher suites available under SSLv3 and under TLS?

Ans:

There are several small differences between the cipher suites available under SSLv3 and under TLS:

Key Exchange: TLS supports all of the key exchange techniques of SSLv3 with the exception of Fortezza. Symmetric Encryption Algorithms: TLS includes all of the symmetric encryption algorithms found in SSLv3, with the exception of Fortezza.

Client Certificate Types

TLS defines the following certificate types to be requested in a certificate_request message: rsa_sign, dss_sign, rsa_fixed_dh, and dss_fixed_dh. These are all defined in SSLv3. In addition, SSLv3 includes rsa_ephemeral_dh, dss_ephemeral_dh, and fortezza_kea. Ephemeral Diffie-Hellman involves signing the Diffie-Hellman parameters with either RSA or DSS; for TLS, the rsa_sign and dss_sign types are used for that function; a separate signing type is not needed to sign Diffie-Hellman parameters. TLS does not include the Fortezza scheme.

Certificate_Verify and Finished Messages

In the TLS certificate_verify message, the MD5 and SHA-1 hashes are calculated only over handshake_messages. For SSLv3, the hash calculation also included the master secret and pads. These extra fields were felt to add no additional security.
As with the finished message in SSLv3, the finished message in TLS is a hash based on the shared master_secret, the previous handshake messages, and a label that identifies client or server. The calculation is somewhat different. For TLS, we have

PRF(master_secret, finished_label, MD5(handshake_messages)||
SHA-1(handshake_messages))

where finished_label is the string "client finished" for the client and "server finished" for the server.

Cryptographic Computations

The pre_master_secret for TLS is calculated in the same way as in SSLv3. As in SSLv3, the master_secret in TLS is calculated as a hash function of the pre_master_secret and the two hello random numbers. The form of the TLS calculation is different from that of SSLv3 and is defined as follows:

master_secret = PRF(pre_master_secret, "master secret",
ClientHello.random || ServerHello.random)

The algorithm is performed until 48 bytes of pseudorandom output are produced. The calculation of the key block material (MAC secret keys, session encryption keys, and IVs) is defined as follows:

key_block = PRF(master_secret, "key expansion",
SecurityParameters.server_random ||
SecurityParameters.client_random)

until enough output has been generated. As with SSLv3, the key_block is a function of the master_secret and the client and server random numbers, but for TLS the actual algorithm is different.

Padding

In SSL, the padding added prior to encryption of user data is the minimum amount required so that the total size of the data to be encrypted is a multiple of the cipher's block length. In TLS, the padding can be any amount that results in a total that is a multiple of the cipher's block length, up to a maximum of 255 bytes. For example, if the plaintext (or compressed text if compression is used) plus MAC plus padding.length byte is 79 bytes long, then the padding length, in bytes, can be 1, 9, 17, and so on, up to 249. A variable padding length may be used to frustrate attacks based on an analysis of the lengths of exchanged messages.

]

TEXTBOOK

Behrouz A. Forouzan, Cryptography & Network Security, Special Indian Edition