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S. Smyshlyaev, Ed.
CryptoPro
D. Belyavskiy
Cryptocom
E. Alekseev
CryptoPro
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GOST Cipher Suites for Transport Layer Security (TLS) Protocol Version 1.2

Abstract

This document specifies three new cipher suites, two new signature algorithms, seven new supported groups, and two new certificate types for the Transport Layer Security (TLS) protocol version 1.2 to support the Russian cryptographic standard algorithms (called "GOST" algorithms). This document specifies a profile of TLS 1.2 with GOST algorithms so that implementers can produce interoperable implementations.

This specification facilitates implementations that aim to support the GOST algorithms. This document does not imply IETF endorsement of the cipher suites, signature algorithms, supported groups, and certificate types.

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Contributors

Authors' Addresses

1. Introduction

This document specifies three new cipher suites, two new signature algorithms, seven new supported groups, and two new certificate types for the Transport Layer Security (TLS) protocol version 1.2 [RFC5246] (note that [RFC5246] has been obsoleted by [RFC8446]) to support the set of Russian cryptographic standard algorithms (called "GOST" algorithms). This document specifies a profile of TLS 1.2 with GOST algorithms so that implementers can produce interoperable implementations. The profile of TLS 1.2 with GOST algorithms uses the hash algorithm GOST R 34.11-2012 [RFC6986], the signature algorithm GOST R 34.10-2012 [RFC7091], and two types of cipher suites: the CTR_OMAC and the CNT_IMIT.

The CTR_OMAC cipher suites use the GOST R 34.12-2015 (see [RFC7801] and [RFC8891]) block ciphers.

The CNT_IMIT cipher suite uses the GOST 28147-89 [RFC5830] block cipher.

This document specifies the profile of the TLS protocol version 1.2 with GOST algorithms. The profile of the TLS protocol version 1.3 [RFC8446] with GOST algorithms is specified in a separate document [DraftGostTLS13].

This specification facilitates implementations that aim to support the GOST algorithms. This document does not imply IETF endorsement of the cipher suites, signature algorithms, supported groups, and certificate types.

2. Conventions Used in This Document

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in BCP 14 [RFC2119] [RFC8174] when, and only when, they appear in all capitals, as shown here.

3. Basic Terms and Definitions

This document follows the terminology from [RFC8446bis] for "preliminary secret" and "extended_main_secret".

This document uses the following terms and definitions for the sets and operations on the elements of these sets:

B_t	the set of byte strings of length t , $t \geq 0$. For $t = 0$, the B_t set consists of a single empty string of zero length. If A is an element of B_t , then $A = (a_1, a_2, \dots, a_t)$, where a_1, a_2, \dots, a_t are in $\{0, \dots, 255\}$.
B^*	the set of all byte strings of a finite length (hereinafter referred to as "strings"), including the empty string.
$A[i..j]$	the string $A[i..j] = (a_i, a_{i+1}, \dots, a_j)$ in $B_{\{j-i+1\}}$, where $A = (a_1, \dots, a_t)$ in B_t and $1 \leq i \leq j \leq t$.
$L(A)$	the length of the byte string A in bytes.
$A \mid C$	concatenation of strings A and C both belonging to B^* , i.e., a string in $B_{\{L(A)+L(C)\}}$, where the left substring in $B_{L(A)}$ is equal to A and the right substring in $B_{L(C)}$ is equal to C .
$A \text{ XOR } C$	bitwise exclusive-or of byte strings A and C both belonging to B_t (both are of length t bytes), i.e., a string in B_t such that if $A = (a_1, a_2, \dots, a_t)$ and $C = (c_1, c_2, \dots, c_t)$, then $A \text{ XOR } C = (a_1 \text{ (xor) } c_1, a_2 \text{ (xor) } c_2, \dots, a_t \text{ (xor) } c_t)$, where (xor) is bitwise exclusive-or of bytes.
$i \ \& \ j$	bitwise AND of unsigned integers i and j .
STR_t	the transformation that maps an integer $i = 256^{(t-1)} * i_1 + \dots + 256 * i_{t-1} + i_t$ into the byte string $STR_t(i) = (i_1, \dots, i_t)$ in B_t (the interpretation of the integer as a byte string in big-endian format).
str_t	the transformation that maps an integer $i = 256^{(t-1)} * i_t + \dots + 256 * i_2 + i_1$ into the byte string $str_t(i) = (i_1, \dots, i_t)$ in B_t (the interpretation of the integer as a byte string in little-endian format).
INT	the transformation that maps a string $a = (a_1, \dots, a_t)$ in B_t into the integer $INT(a) = 256^{(t-1)} * a_1 + \dots + 256 * a_{t-1} + a_t$ (the interpretation of the byte string in big-endian format as an integer).
int	the transformation that maps a string $a = (a_1, \dots, a_t)$ in B_t into the integer $int(a) = 256^{(t-1)} * a_t + \dots + 256 * a_2 + a_1$ (the interpretation of the byte string in little-endian format as an integer).
k	the length of the block cipher key in bytes.
n	the length of the block cipher block in bytes.
Q_c	the public key stored in the client's certificate.
d_c	the private key that corresponds to the Q_c key.

Q_s the public key stored in the server's certificate.

d_s the private key that corresponds to the Q_s key.

q_s an order of a cyclic subgroup of the elliptic curve points group containing point Q_s.

P_s the distinguished generator of the subgroup of order q_s that belongs to the same curve as Q_s.

r_c the random string contained in the ClientHello.random field (see [RFC5246]).

r_s the random string contained in the ServerHello.random field (see [RFC5246]).

4. Cipher Suite Definitions

This document specifies the CTR_OMAC cipher suites and the CNT_IMIT cipher suite.

The CTR_OMAC cipher suites have the following values:

```
TLS_GOSTR341112_256_WITH_KUZNYECHIK_CTR_OMAC = {0xC1, 0x00};
TLS_GOSTR341112_256_WITH_MAGMA_CTR_OMAC = {0xC1, 0x01}.
```

The CNT_IMIT cipher suite has the following value:

```
TLS_GOSTR341112_256_WITH_28147_CNT_IMIT = {0xC1, 0x02}.
```

4.1. Record Payload Protection

The profile of TLS 1.2 with GOST algorithms requires that the compression not be used.

All of the cipher suites described in this document use such modes of operation (see Section 4.3.3) that protect the records in the same way as if they were protected by a stream cipher. The TLSCiphertext structure for the CTR_OMAC and CNT_IMIT cipher suites is specified in accordance with the standard stream cipher case (see Section 6.2.3.1 of [RFC5246]):

```
struct {
    ContentType type;
    ProtocolVersion version;
    uint16 length;
    GenericStreamCipher fragment;
} TLSCiphertext;
```

where TLSCiphertext.fragment is generated in accordance with Section 4.1.1 when the CTR_OMAC cipher suites are used and Section 4.1.2 when the CNT_IMIT cipher suite is used.

The connection key material is a key material that consists of the sender_write_key (either the client_write_key or the

server_write_key), the sender_write_MAC_key (either the client_write_MAC_key or the server_write_MAC_key), and the sender_write_IV (either the client_write_IV or the server_write_IV) parameters that are generated in accordance with Section 6.3 of [RFC5246].

The record key material is a key material that is generated from the connection key material and is used to protect a record with a certain sequence number. Note that with some cipher suites defined in this document, the record key material can be equal to the connection key material.

In this section, the TLSCiphertext.fragment generation is described for one particular endpoint (server or client) with the corresponding connection key material and record key material.

4.1.1. CTR_OMAC

In the CTR_OMAC cipher suites, the record key material differs from the connection key material, and for the seqnum sequence number consists of:

K_ENC_seqnum in B_k;

K_MAC_seqnum in B_k; and

IV_seqnum in B_{n/2}.

The K_ENC_seqnum and K_MAC_seqnum values are calculated using the TLSTREE function defined in Section 8.1, the connection key material, and the seqnum sequence number. IV_seqnum is calculated by adding the seqnum value to sender_write_IV modulo $2^{((n/2)*8)}$:

$K_ENC_seqnum = TLSTREE(sender_write_key, seqnum);$

$K_MAC_seqnum = TLSTREE(sender_write_MAC_key, seqnum);$ and

$IV_seqnum = STR_{\{n/2\}}((INT(sender_write_IV) + seqnum) \bmod 2^{\{(n/2)*8\}}).$

The TLSCiphertext.fragment that corresponds to the seqnum sequence number is calculated as follows:

1. The MACValue_seqnum value is generated using the Message Authentication Code (MAC) algorithm (see Section 4.3.2) similar to Section 6.2.3.1 of [RFC5246], except the sender_write_MAC_key is replaced by the K_MAC_seqnum key:

$MACValue_seqnum = MAC(K_MAC_seqnum, STR_8(seqnum) \parallel type_seqnum \parallel version_seqnum \parallel length_seqnum \parallel fragment_seqnum),$

where type_seqnum, version_seqnum, length_seqnum, and fragment_seqnum are the TLSCompressed.type, TLSCompressed.version, TLSCompressed.length, and TLSCompressed.fragment values of the record with the seqnum sequence number.

2. The entire data with the MACValue is encrypted with the ENC stream cipher (see Section 4.3.3):

ENCValue_seqnum = ENC(K_ENC_seqnum, IV_seqnum, fragment_seqnum | MACValue_seqnum),

where fragment_seqnum is the TLSCompressed.fragment value of the record with the seqnum sequence number.

3. The fields of the GenericStreamCipher structure (see Section 6.2.3.1 of [RFC5246]) for the TLSCiphertext.fragment value are defined by the ENCValue_seqnum value:

TLSCiphertext.fragment.content =
ENCValue_seqnum[1..length_seqnum],

TLSCiphertext.fragment.MAC = ENCValue_seqnum[length_seqnum + 1..length_seqnum + mac_length],

where length_seqnum is the TLSCompressed.length value of the record with the seqnum sequence number and mac_length is equal to 16 for the TLS_GOSTR341112_256_WITH_KUZNYECHIK_CTR_OMAC cipher suite and 8 for the TLS_GOSTR341112_256_WITH_MAGMA_CTR_OMAC cipher suite.

Note that the CTR_OMAC cipher suites use the authenticate-then-encrypt method (see Appendix F.4 of [RFC5246]). Since these ciphers are functioning as stream ciphers, the authenticate-then-encrypt method is secure, and as specified by [RFC7366], the server that selects the CTR_OMAC ciphers MUST NOT send an encrypt_then_mac extension to the client.

4.1.2. CNT_IMIT

In the CNT_IMIT cipher suite, the record key material is equal to the connection key material and consists of:

sender_write_key in B_k;

sender_write_MAC_key in B_k; and

sender_write_IV in B_n.

The TLSCiphertext.fragment that corresponds to the seqnum sequence number is calculated as follows:

1. The MACValue_seqnum value is generated by the MAC algorithm (see Section 4.3.2) as follows:

MACValue_seqnum = MAC(sender_write_MAC_key, STR_8(0) | type_0 | version_0 | length_0 | fragment_0 | ... | STR_8(seqnum) | type_seqnum | version_seqnum | length_seqnum | fragment_seqnum),

where type_i, version_i, length_i, fragment_i, and i in {0, ... , seqnum} are the TLSCompressed.type, TLSCompressed.version,

TLSCompressed.length, and TLSCompressed.fragment values of the record with the *i* sequence number.

Due to the use of the mode based on Cipher Block Chaining MAC (CBC-MAC) (see Section 4.3.2), producing the MACValue_seqnum value does not mean processing all previous records. It is enough to store only an intermediate internal state of the MAC algorithm.

2. The entire data with the MACValue is encrypted with the ENC stream cipher (see Section 4.3.3):

```
ENCValue_0 | ... | ENCValue_seqnum = ENC(sender_write_key,  
sender_write_IV, fragment_0 | MACValue_0 | ... | fragment_seqnum |  
MACValue_seqnum),
```

where the length of the byte string ENCValue_*i* in bytes is equal to the length of the byte string (fragment_*i* | MACValue_*i*) in bytes and *i* in {0, ... , seqnum}.

Due to the use of the stream cipher (see Section 4.3.3), producing the ENCValue_seqnum value does not mean processing all previous records. It is enough to store only an intermediate internal state of the ENC stream cipher.

3. The fields of the GenericStreamCipher structure (see Section 6.2.3.1 of [RFC5246]) for the TLSCiphertext.fragment value are defined by the ENCValue_seqnum value:

```
TLSCiphertext.fragment.content =  
ENCValue_seqnum[1..length_seqnum],
```

```
TLSCiphertext.fragment.MAC = ENCValue_seqnum[length_seqnum +  
1..length_seqnum + mac_length],
```

where length_seqnum is the TLSCompressed.length value of the record with the seqnum sequence number, and mac_length is equal to 4.

Note that the CNT_IMIT cipher suite uses the authenticate-then-encrypt method (see Appendix F.4 of [RFC5246]). Since this cipher is functioning as a stream cipher, the authenticate-then-encrypt method is secure, and as specified by [RFC7366], the server that selects the CNT_IMIT cipher MUST NOT send an encrypt_then_mac extension to the client.

4.2. Key Exchange and Authentication

The cipher suites defined in this document use a key encapsulation mechanism based on Diffie-Hellman to share the TLS preliminary secret.

Client

Server

ClientHello

----->

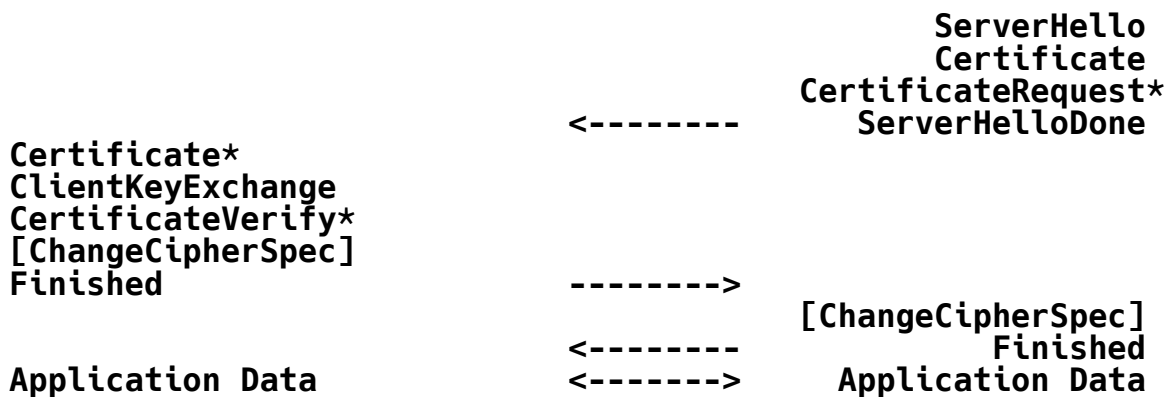


Figure 1: Message Flow for a Full Handshake

Notes for Figure 1:

1. "*" indicates optional messages that are sent for the client authentication.
2. To help avoid pipeline stalls, **ChangeCipherSpec** is an independent TLS protocol content type and is not actually a TLS handshake message.

Figure 1 shows all messages involved in the TLS key establishment protocol (full handshake). A **ServerKeyExchange** MUST NOT be sent (the server's certificate contains enough data to allow the client to exchange the preliminary secret).

The server side of the channel is always authenticated; the client side is optionally authenticated. The server is authenticated by proving that it knows the preliminary secret that is encrypted with the public key Q_s from the server's certificate. The client is authenticated via its signature over the handshake transcript.

In general, the key exchange process for both the **CTR_OMAC** and **CNT_IMIT** cipher suites consists of the following steps:

1. The client generates the ephemeral key pair (d_{eph} , Q_{eph}) that corresponds to the server's public key Q_s stored in its certificate.
2. The client generates the preliminary secret PS. The PS value is chosen from B_{32} at random.
3. Using d_{eph} and Q_s , the client generates the export key material (see Sections 4.2.4.1 and 4.2.4.2) for the particular key export algorithm (see Sections 8.2.1 and 8.2.2) to generate the export representation **PSExp** of the PS value.
4. The client sends its ephemeral public key Q_{eph} and **PSExp** value in the **ClientKeyExchange** message.
5. Using its private key d_s , the server generates the import key material (see Sections 4.2.4.1 and 4.2.4.2) for the particular key import algorithm (see Sections 8.2.1 and 8.2.2) to extract

the preliminary secret PS from the export representation PSEXP.

This section specifies the data structures and computations used by the profile of TLS 1.2 with GOST algorithms. The specifications for the ClientHello, ServerHello, Server Certificate, CertificateRequest, ClientKeyExchange, CertificateVerify, and Finished handshake messages are described in further detail below.

4.2.1. Hello Messages

The ClientHello message is generated in accordance with Section 7.4.1.2 of [RFC5246] and must meet the following requirements:

- * The ClientHello.compression_methods field MUST contain exactly one byte, set to zero, which corresponds to the "null" compression method.
- * The ClientHello.extensions field MUST contain the signature_algorithms extension (see [RFC5246]).

If the negotiated cipher suite is one of CTR_OMAC/CTR_IMIT and the signature_algorithms extension in the ClientHello message does not contain the values defined in Section 5, the server MUST either abort the connection or ignore this extension and behave as if the client had sent the signature_algorithms extension with the values {8, 64} and {8, 65}.

The ServerHello message is generated in accordance with Section 7.4.1.3 of [RFC5246] and must meet the following requirements:

- * The ServerHello.compression_method field MUST contain exactly one byte, set to zero, which corresponds to the "null" compression method.
- * The ServerHello.extensions field MUST NOT contain the encrypt_then_mac extension (see [RFC7366]).

4.2.2. Server Certificate

This message is used to authentically convey the server's public key Q_s to the client and is generated in accordance with Section 7.4.2 of [RFC5246].

Upon receiving this message, the client validates the certificate chain, extracts the server's public key, and checks that the key type is appropriate for the negotiated key exchange algorithm. (A possible reason for a fatal handshake failure is that the client's capabilities for handling elliptic curves and point formats are exceeded).

4.2.3. CertificateRequest

This message is sent by the server when requesting client authentication and is generated in accordance with Section 7.4.4 of

[RFC5246].

If the CTR_OMAC or CNT_IMIT cipher suite is negotiated, the CertificateRequest message MUST meet the following requirements:

- * the CertificateRequest.supported_signature_algorithm field MUST contain only signature/hash algorithm pairs with the values {8, 64} or {8, 65} defined in Section 5;
- * the CertificateRequest.certificate_types field MUST contain only the gost_sign256 (67) or gost_sign512 (68) values defined in Section 7.

4.2.4. ClientKeyExchange

The ClientKeyExchange message is defined as follows:

```
enum { vko_kdf_gost, vko_gost } KeyExchangeAlgorithm;  
  
struct {  
    select (KeyExchangeAlgorithm) {  
        case vko_kdf_gost: GostKeyTransport;  
        case vko_gost: TLSGostKeyTransportBlob;  
    } exchange_keys;  
} ClientKeyExchange;
```

The body of the ClientKeyExchange message consists of a GostKeyTransport/TLSGostKeyTransportBlob structure that contains an export representation of the preliminary secret PS.

The GostKeyTransport structure corresponds to the CTR_OMAC cipher suites and is described in Section 4.2.4.1, and the TLSGostKeyTransportBlob structure corresponds to the CNT_IMIT cipher suite and is described in Section 4.2.4.2.

The DER encoding rules are used to encode the GostKeyTransport and the TLSGostKeyTransportBlob structures.

4.2.4.1. CTR_OMAC

In the CTR_OMAC cipher suites, the body of the ClientKeyExchange message consists of the GostKeyTransport structure that is defined below.

The client generates the ClientKeyExchange message in accordance with the following steps:

1. Generates the ephemeral key pair (Q_eph, d_eph), where:
 d_eph is chosen from {1, ... , q_s - 1} at random;
 Q_eph = d_eph * P_s.
2. Generates the preliminary secret PS, where PS is chosen from B_32 at random.

3. Generates export keys (K_EXP_MAC and K_EXP_ENC) using the KEG algorithm defined in Section 8.3.1:

$H = \text{HASH}(r_c \parallel r_s);$

$K_EXP_MAC \parallel K_EXP_ENC = \text{KEG}(d_{eph}, Q_s, H).$

4. Generates an export representation PSExp of the preliminary secret PS using the KExp15 algorithm defined in Section 8.2.1:

$IV = H[25..24 + n / 2];$

$PSExp = \text{KExp15}(PS, K_EXP_MAC, K_EXP_ENC, IV).$

5. Generates the ClientKeyExchange message using the GostKeyTransport structure that is defined as follows:

```
GostKeyTransport ::= SEQUENCE {  
    keyExp          OCTET STRING,  
    ephemeralPublicKey SubjectPublicKeyInfo,  
    ukm             OCTET STRING OPTIONAL  
}
```

```
SubjectPublicKeyInfo ::= SEQUENCE {  
    algorithm      AlgorithmIdentifier,  
    subjectPublicKey BIT STRING  
}
```

```
AlgorithmIdentifier ::= SEQUENCE {  
    algorithm      OBJECT IDENTIFIER,  
    parameters    ANY OPTIONAL  
}
```

where the keyExp field contains the PSExp value, the ephemeralPublicKey field contains the Q_eph value, and the ukm field MUST be ignored by the server.

Upon receiving the ClientKeyExchange message, the server process is as follows.

1. The following three conditions are checked. If any of these checks fail, then the server MUST abort the handshake with an alert.
 - * Q_{eph} belongs to the same curve as server public key Q_s ;
 - * Q_{eph} is not equal to zero point;
 - * $q_s * Q_{eph}$ is equal to zero point.
2. The export keys (K_EXP_MAC and K_EXP_ENC) are generated using the KEG algorithm defined in Section 8.3.1:

$H = \text{HASH}(r_c \parallel r_s);$

$K_EXP_MAC \parallel K_EXP_ENC = \text{KEG}(d_s, Q_{eph}, H).$

3. The preliminary secret PS is extracted from the export representation PSExp using the KImp15 algorithm defined in Section 8.2.1:

$IV = H[25..24 + n / 2];$

$PS = KImp15(PSExp, K_EXP_MAC, K_EXP_ENC, IV).$

4.2.4.2. CNT_IMIT

In the CNT_IMIT cipher suite, the body of the ClientKeyExchange message consists of a TLSGostKeyTransportBlob structure that is defined below.

The client generates the ClientKeyExchange message in accordance with the following steps:

1. The ephemeral key pair (Q_eph, d_eph) is generated, where:

d_eph is chosen from {1, ... , q_s - 1} at random;

$Q_eph = d_eph * P_s.$

2. The preliminary secret PS is generated, where PS is chosen from B_32 at random.
3. The export key (K_EXP) is generated using the KEG_28147 algorithm defined in Section 8.3.2:

$H = HASH(r_c \parallel r_s);$

$K_EXP = KEG_28147(d_eph, Q_s, H).$

4. An export representation PSExp of the preliminary secret PS using the KExp28147 algorithm defined in Section 8.2.2 is generated:

$PSExp = IV \parallel CEK_ENC \parallel CEK_MAC = KExp28147(PS, K_EXP, H[1..8]).$

5. The ClientKeyExchange message is generated using the TLSGostKeyTransportBlob structure that is defined as follows:

```

TLSGostKeyTransportBlob ::= SEQUENCE {
    keyBlob                GostR3410-KeyTransport
}
GostR3410-KeyTransport ::= SEQUENCE {
    sessionEncryptedKey    Gost28147-89-EncryptedKey,
    transportParameters    [0] IMPLICIT GostR3410-
                           TransportParameters OPTIONAL
}
Gost28147-89-EncryptedKey ::= SEQUENCE {
    encryptedKey            Gost28147-89-Key,
    maskKey                 [0] IMPLICIT Gost28147-89-Key OPTIONAL,
    macKey                  Gost28147-89-MAC
}
GostR3410-TransportParameters ::= SEQUENCE {
    encryptionParamSet     OBJECT IDENTIFIER,

```

```

    ephemeralPublicKey  [0] IMPLICIT SubjectPublicKeyInfo
                                OPTIONAL,
    ukm                  OCTET STRING
}

```

where GostR3410-KeyTransport, Gost28147-89-EncryptedKey, and GostR3410-TransportParameters are defined according to Section 4.2.1 of [RFC4490].

In the context of this document, the GostR3410-KeyTransport.transportParameters field is always used, the Gost28147-89-EncryptedKey.maskKey field is omitted, and the GostR3410-KeyTransport.transportParameters.ephemeralPublicKey field is always used.

The Gost28147-89-EncryptedKey.encryptedKey field contains the CEK_ENC value, the Gost28147-89-EncryptedKey.macKey field contains the CEK_MAC value, and the GostR3410-TransportParameters.ukm field contains the initialization vector (IV) value.

The keyBlob.transportParameters.ephemeralPublicKey field contains the client ephemeral public key Q_{eph} . The encryptionParamSet contains the value 1.2.643.7.1.2.5.1.1, which corresponds to the id-tc26-gost-28147-param-Z parameters set defined in [RFC7836].

Upon receiving the ClientKeyExchange message, the server process is as follows.

1. The following three conditions are checked. If either of these checks fails, then the server MUST abort the handshake with an alert.
 - * Q_{eph} belongs to the same curve as server public key Q_s ;
 - * Q_{eph} is not equal to zero point;
 - * $q_s * Q_{eph}$ is equal to zero point.
2. The export key (K_{EXP}) is generated using the KEG_28147 algorithm defined in Section 8.3.2:

$$H = \text{HASH}(r_c \parallel r_s);$$

$$K_{EXP} = \text{KEG_28147}(d_s, Q_{eph}, H).$$

3. The preliminary secret PS is extracted from the export representation PSExp using the KImp28147 algorithm defined in Section 8.2.2:

$$PS = \text{KImp28147}(\text{PSExp}, K_{EXP}, H[1..8]).$$

4.2.5. CertificateVerify

The client generates the value sgn as follows:

$$\text{sgn} = \text{SIGN}_{\{d_c\}}(\text{handshake_messages}) = \text{str}_l(r) \parallel \text{str}_l(s)$$

where `SIGN_{d_c}` is the GOST R 34.10-2012 [RFC7091] signature algorithm, `d_c` is a client long-term private key that corresponds to the client long-term public key `Q_c` from the client's certificate, `l = 32` for the `gostr34102012_256` value of the `SignatureAndHashAlgorithm` field, and `l = 64` for the `gostr34102012_512` value of the `SignatureAndHashAlgorithm` field.

Here, "handshake_messages" refers to all handshake messages sent or received, starting at `ClientHello` and up to `CertificateVerify` without the last message; it includes the type and length fields of the handshake messages.

The TLS `CertificateVerify` message is specified as follows:

```
struct {  
    SignatureAndHashAlgorithm algorithm;  
    opaque signature<0..2^16-1>;  
} CertificateVerify;
```

where the `SignatureAndHashAlgorithm` structure is specified in Section 5, and the `CertificateVerify.signature` field contains the `sgn` value.

4.2.6. Finished

The TLS `Finished` message is generated in accordance with Section 7.4.9 of [RFC5246].

The `verify_data_length` value is equal to 32 for the `CTR_OMAC` cipher suites and is equal to 12 for the `CNT_IMIT` cipher suite. The pseudorandom function (PRF) is defined in Section 4.3.4.

4.3. Cryptographic Algorithms

4.3.1. Block Cipher

The cipher suite `TLS_GOSTR341112_256_WITH_KUZNYECHIK_CTR_OMAC` MUST use Kuznyechik [RFC7801] as a base block cipher for the encryption and MAC algorithm. The block length `n` is 16 bytes, and the key length `k` is 32 bytes.

The cipher suite `TLS_GOSTR341112_256_WITH_MAGMA_CTR_OMAC` MUST use Magma [RFC8891] as a base block cipher for the encryption and MAC algorithm. The block length `n` is 8 bytes, and the key length `k` is 32 bytes.

The cipher suite `TLS_GOSTR341112_256_WITH_28147_CNT_IMIT` MUST use GOST 28147-89 as a base block cipher [RFC5830] with the set of parameters `id-tc26-gost-28147-param-Z` defined in [RFC7836]. The block length `n` is 8 bytes, and the key length `k` is 32 bytes.

4.3.2. MAC Algorithm

The `CTR_OMAC` cipher suites use the One-Key MAC (OMAC) construction defined in [GOST3413-2015], which is the same as the Cipher-Based MAC

(CMAC) mode defined in [CMAC] where the Kuznyechik or Magma block cipher (see Section 4.3.1) is used instead of the AES block cipher (see [IK2003] for more detail) as the MAC function. The resulting MAC length is equal to the block length, and the MAC key length is 32 bytes.

The CNT_IMIT cipher suite uses the MAC function gostIMIT28147 defined in Section 8.4 with the initialization vector $IV = IV_0$, where IV_0 in B.8 is a string of all zeros, with the CryptoPro Key Meshing algorithm defined in [RFC4357]. The resulting MAC length is 4 bytes, and the MAC key length is 32 bytes.

4.3.3. Encryption Algorithm

The CTR_OMAC cipher suites use the block cipher in the CTR-ACPKM encryption mode defined in [RFC8645] as the ENC function. The section size N is 4 KB for the TLS_GOSTR341112_256_WITH_KUZNYECHIK_CTR_OMAC cipher suite and 1 KB for the TLS_GOSTR341112_256_WITH_MAGMA_CTR_OMAC cipher suite.

The CNT_IMIT cipher suite uses the block cipher in counter encryption mode (CNT) defined in Section 6 of [RFC5830], with the CryptoPro key meshing algorithm defined in [RFC4357] as the ENC function.

Note that the counter modes used in cipher suites described in this document act as stream ciphers.

4.3.4. PRF and HASH Algorithms

The PRF for all the cipher suites defined in this document is the PRF_TLS_GOSTR3411_2012_256 function defined in [RFC7836].

The hash function HASH for all the cipher suites defined in this document is the GOST R 34.11-2012 [RFC6986] hash algorithm with a 32-byte (256-bit) hash code.

4.3.5. SNMAX Parameter

The SNMAX parameter defines the maximal value of the seqnum sequence number during one TLS 1.2 connection and is defined as follows:

Cipher Suites	SNMAX
TLS_GOSTR341112_256_WITH_KUZNYECHIK_CTR_OMAC TLS_GOSTR341112_256_WITH_28147_CNT_IMIT	SNMAX = $2^{64} - 1$
TLS_GOSTR341112_256_WITH_MAGMA_CTR_OMAC	SNMAX = $2^{32} - 1$

Table 1

5. New Values for the TLS SignatureAlgorithm Registry

The signature/hash algorithm pairs are used to indicate to the

server/client which algorithms can be used in digital signatures and are defined by the SignatureAndHashAlgorithm structure (see Section 7.4.1.4.1 of [RFC5246]).

This document defines new values for the "TLS SignatureAlgorithm" registry that can be used in the SignatureAndHashAlgorithm.signature field for the particular signature/hash algorithm pair:

```
enum {  
    gostr34102012_256(64),  
    gostr34102012_512(65),  
} SignatureAlgorithm;
```

where the gostr34102012_256 and gostr34102012_512 values correspond to the GOST R 34.10-2012 [RFC7091] signature algorithm with a 32-byte (256-bit) and 64-byte (512-bit) key length, respectively.

According to [RFC7091], the GOST R 34.10-2012 signature algorithm with a 32-byte (256-bit) or 64-byte (512-bit) key length uses the GOST R 34.11-2012 [RFC6986] hash algorithm with a 32-byte (256-bit) or 64-byte (512-bit) hash code, respectively (the hash algorithm is intrinsic to the signature algorithm). Therefore, if the SignatureAndHashAlgorithm.signature field of a particular hash/signature pair listed in the Signature Algorithms Extension is equal to the 64 (gostr34102012_256) or 65 (gostr34102012_512) value, the SignatureAndHashAlgorithm.hash field of this pair MUST contain the "Intrinsic" value 8 (see [RFC8422]).

So, to represent gostr34102012_256 and gostr34102012_512 in the signature_algorithms extension, the value shall be (8,64) and (8,65), respectively.

6. New Values for the TLS Supported Groups Registry

The Supported Groups Extension indicates the set of elliptic curves supported by the client and is defined in [RFC8422] and [RFC7919].

This document defines new values for the "TLS Supported Groups" registry:

```
enum {  
    GC256A(34), GC256B(35), GC256C(36), GC256D(37),  
    GC512A(38), GC512B(39), GC512C(40),  
} NamedGroup;
```

where the values correspond to the following curves:

Description	Curve Identifier Value	Reference
GC256A	id-tc26-gost-3410-2012-256-paramSetA	[RFC7836]
GC256B	id-GostR3410-2001-CryptoPro-A-ParamSet	[RFC4357]
GC256C	id-GostR3410-2001-CryptoPro-B-ParamSet	[RFC4357]

GC256D	id-GostR3410-2001-CryptoPro-C-ParamSet	[RFC4357]	
+-----+	+-----+	+-----+	+-----+
GC512A	id-tc26-gost-3410-12-512-paramSetA	[RFC7836]	
+-----+	+-----+	+-----+	+-----+
GC512B	id-tc26-gost-3410-12-512-paramSetB	[RFC7836]	
+-----+	+-----+	+-----+	+-----+
GC512C	id-tc26-gost-3410-2012-512-paramSetC	[RFC7836]	
+-----+	+-----+	+-----+	+-----+

Table 2

7. New Values for the TLS ClientCertificateType Identifiers Registry

The ClientCertificateType field of the CertificateRequest message contains a list of certificate types that the client may offer and is defined in Section 7.4.4 of [RFC5246].

This document defines new values for the "TLS ClientCertificateType Identifiers" registry:

```
enum {
    gost_sign256(67),
    gost_sign512(68),
} ClientCertificateType;
```

To use the gost_sign256 or gost_sign512 authentication mechanism, the client MUST possess a certificate containing a GOST R 34.10-2012-capable public key that corresponds to the 32-byte (256-bit) or 64-byte (512-bit) signature key, respectively.

The client proves possession of the private key corresponding to the certified key by including a signature in the CertificateVerify message as described in Section 4.2.5.

8. Additional Algorithms

The cipher suites specified in this document rely on some additional algorithms, specified below; the use of these algorithms is not confined to the use in TLS specified in this document.

8.1. TLSTREE

The TLSTREE function is defined as follows:

```
TLSTREE(K_root, i) = KDF_3(KDF_2(KDF_1(K_root, STR_8(i & C_1)),
STR_8(i & C_2)), STR_8(i & C_3)),
```

where

- * K_root in B_32;
- * i in {0, 1, ... , 2⁶⁴ - 1};
- * C_1, C_2, C_3 are constants defined by the particular cipher suite (see Section 8.1.1);

* $KDF_j(K, D)$, $j = 1, 2, 3$, K in B_{32} , D in B_8 , is the key derivation function based on the $KDF_GOSTR3411_2012_256$ function defined in [RFC7836]:

$KDF_1(K, D) = KDF_GOSTR3411_2012_256(K, "level1", D)$;

$KDF_2(K, D) = KDF_GOSTR3411_2012_256(K, "level2", D)$; and

$KDF_3(K, D) = KDF_GOSTR3411_2012_256(K, "level3", D)$.

8.1.1. Key Tree Parameters

The CTR_OMAC cipher suites use the TLSTREE function for the rekeying approach. The constants for it are defined as in the table below.

Cipher Suites	C_1, C_2, C_3
TLS_GOSTR341112_256_WITH_KUZNYECHIK_CTR_OMAC	C_1=0xFFFFFFFF00000000 C_2=0xFFFFFFFFFFFF80000 C_3=0xFFFFFFFFFFFFFC0
TLS_GOSTR341112_256_WITH_MAGMA_CTR_OMAC	C_1=0xFFFFF00000000000 C_2=0xFFFFFFFFFE000000 C_3=0xFFFFFFFFFFFF000

Table 3

8.2. Key Export and Key Import Algorithms

8.2.1. KExp15 and KImp15 Algorithms

Algorithms KExp15 and KImp15 use the block cipher determined by the particular cipher suite.

The KExp15 key export algorithm is defined as follows:

KExp15(S, K_Exp_MAC, K_Exp_ENC, IV) <hr/> Input: - secret S to be exported, S in B^* , - key K_Exp_MAC in B_k , - key K_Exp_ENC in B_k , - IV in $B_{\{n/2\}}$ Output: - export representation SExp in $B_{\{L(S)+n\}}$ <hr/> 1. $CEK_MAC = OMAC(K_Exp_MAC, IV \parallel S)$, CEK_MAC in B_n 2. $SExp = CTR-Encrypt(K_Exp_ENC, IV, S \parallel CEK_MAC)$ 3. return SExp

where the OMAC function is defined in [MODES] and the CTR-Encrypt(K, IV, S) function denotes the encryption of message S on key K and

nonce IV in the CTR mode with $s = n$ (see [MODES]).

The KImp15 key import algorithm is defined as follows:

```
+-----+
| KImp15(SExp, K_Exp_MAC, K_Exp_ENC, IV)
+-----+
| Input:
| - export representation SExp in B*
| - key K_Exp_MAC in B_k,
| - key K_Exp_ENC in B_k,
| - IV in B_{n/2}
| Output:
| - secret S in B_{L(SExp)-n} or FAIL
+-----+
| 1. S | CEK_MAC = CTR-Decrypt(K_Exp_ENC, IV, SExp), CEK_MAC in B_n
| 2. If CEK_MAC = OMAC(K_Exp_MAC, IV | S)
|    then return S; else return FAIL
+-----+
```

where the OMAC function is defined in [MODES] and the CTR-Decrypt(K, IV, S) function denotes the decryption of message S on key K and nonce IV in the CTR mode (see [MODES]).

The keys K_Exp_MAC and K_Exp_ENC MUST be independent. For every pair of keys (K_Exp_ENC, K_Exp_MAC), the IV values MUST be unique. For the import of a key with the KImp15 algorithm, the IV value may be sent with the export key representation.

8.2.2. KExp28147 and KImp28147 Algorithms

The KExp28147 key export algorithm is defined as follows:

```
+-----+
| KExp28147(S, K, IV)
+-----+
| Input:
| - secret S to be exported, S in B_32,
| - key K in B_32,
| - IV in B_8.
| Output:
| - export representation SExp in B_44
+-----+
| 1. CEK_MAC = gost28147IMIT(IV, K, S), CEK_MAC in B_4
| 2. CEK_ENC = ECB-Encrypt(K, S), CEK_ENC in B_32
| 3. return SExp = IV | CEK_ENC | CEK_MAC
+-----+
```

where the gost28147IMIT function is defined in Section 8.4 and the ECB-Encrypt(K, S) function denotes the encryption of message S on key K with the block cipher GOST 28147-89 in the electronic codebook (ECB) mode (see [RFC5830]).

The KImp28147 key import algorithm is defined as follows:

```
+-----+
```

KImp28147(SExp, K, IV)
Input: - export representation SExp in B_44, - key K in B_32, - IV in B_8. Output: - imported secret S in B_32 or FAIL
1. extract from SExp IV' = SExp[1..8], CEK_ENC = SExp[9..40], CEK_MAC = SExp[41..44] 2. if IV' != IV then return FAIL; else 3. S = ECB-Decrypt(K, CEK_ENC), S in B_32 4. If CEK_MAC = gost28147IMIT(IV, K, S) then return S; else return FAIL

where the gost28147IMIT function is defined in Section 8.4 and the ECB-Decrypt(CEK_ENC, M) function denotes the decryption of ciphertext CEK_ENC on key \bar{K} with a block cipher GOST 28147-89 in the ECB mode (see [RFC5830]).

8.3. Key Exchange Generation Algorithms

8.3.1. KEG Algorithm

The KEG algorithm is defined as follows:

KEG(d, Q, H)
Input: - private key d, - public key Q, - H in B_32. Output: - key material K in B_64.
1. If $q * Q$ is not equal to zero point return FAIL 2. If $2^{254} < q < 2^{256}$ return KEG_256(d, Q, H) 3. If $2^{508} < q < 2^{512}$ return KEG_512(d, Q, H) 4. return FAIL

where q is an order of a cyclic subgroup of elliptic curve points group containing point Q , d in $\{1, \dots, q - 1\}$.

The KEG_256 algorithm is defined as follows:

KEG_256(d, Q, H)

```

-----
Input:
- private key d,
- public key Q,
- H in B_32.
Output:
- key material K in B_64.
-----

```

```

-----
1. r = INT(H[1..16])
2. If r = 0
    UKM = 1; else UKM = r
3. K_EXP = VKO_256(d, Q, UKM)
4. seed = H[17..24]
5. return KDFTREE_256(K_EXP, "kdf tree", seed, 1)
-----

```

where VKO_256 is the function VKO_GOSTR3410_2012_256 defined in [RFC7836] and KDFTREE_256 is the KDF_TREE_GOSTR3411_2012_256 function defined in [RFC7836] with the parameter L equal to 512.

The KEG_512 algorithm is defined as follows:

```

-----
KEG_512(d, Q, H)
-----
Input:
- private key d,
- public key Q,
- H in B_32.
Output:
- key material K in B_64.
-----
1. r = INT(H[1..16])
2. If r = 0
    UKM = 1; else UKM = r
3. return VKO_512(d, Q, UKM)
-----

```

where VKO_512 is the VKO_GOSTR3410_2012_512 function defined in [RFC7836].

8.3.2. KEG_28147 Algorithm

The KEG_28147 algorithm is defined as follows:

```

-----
KEG_28147(d, Q, H)
-----
Input:
- private key d,
- public key Q,
- H in B_32.
Output:
- key material K in B_32.
-----
1. If q * Q is not equal to zero point

```

```

        return FAIL
2. UKM = H[1..8]
3. R = VKO_256(d, Q, int(UKM))
4. return K = CPDivers(UKM, R)

```

where the VKO_256 function is equal to the VKO_GOSTR3410_2012_256 function defined in [RFC7836] and the CPDivers function corresponds to the CryptoPro KEK Diversification Algorithm defined in [RFC4357], which takes as input the User Keying Material (UKM) value and the key value.

8.4. gostIMIT28147

gost28147IMIT(IV, K, M) is a MAC algorithm with a 4-byte output and is defined as follows:

```

gost28147IMIT(IV, K, M)

```

Input:

- initial value IV in B_8,
- key K in B_32,
- message M in B*.

Output:

- MAC value T in B_4.

- ```

1. M' = PAD(M)
2. M' = M'_0 | ... | M'_r, L(M'_i) = 8, i in {0, ... , r}
3. M'' = (M'_0 XOR IV) | M'_1 | ... | M'_r
4. return T = MAC28147(K, M'')

```

where the PAD function is the padding function that adds m zero bytes to the end of the message, m is the smallest, non-negative solution to the equation  $(L(M) + m) \bmod 8 = 0$ , and the MAC28147 function corresponds to the MAC generation mode defined in [RFC5830] with a 4-byte length output.

#### 9. IANA Considerations

IANA has added the following values to the "TLS Cipher Suites" registry:

| Value     | Description                                  | DTLS-OK | Recommended | Reference |
|-----------|----------------------------------------------|---------|-------------|-----------|
| 0xC1,0x00 | TLS_GOSTR341112_256_WITH_KUZNYECHIK_CTR_OMAC | N       | N           | RFC 9189  |
| 0xC1,0x01 | TLS_GOSTR341112_256_WITH_MAGMA_CTR_OMAC      | N       | N           | RFC 9189  |
| 0xC1,0x02 | TLS_GOSTR341112_256_WITH_28147_CNT_IMIT      | N       | N           | RFC 9189  |

Table 4

IANA has added the following values to the "TLS SignatureAlgorithm" registry:

| Value | Description       | DTLS-OK | Reference |
|-------|-------------------|---------|-----------|
| 64    | gostr34102012_256 | Y       | RFC 9189  |
| 65    | gostr34102012_512 | Y       | RFC 9189  |

Table 5

IANA has added the following values to the "TLS SignatureScheme" registry:

| Value  | Description                         | Recommended | Reference |
|--------|-------------------------------------|-------------|-----------|
| 0x0840 | Reserved for backward compatibility | N           | RFC 9189  |
| 0x0841 | Reserved for backward compatibility | N           | RFC 9189  |

Table 6

IANA has also added the following footnote to values 64 and 65 in the "TLS SignatureAlgorithm" registry:

These values were allocated from the Reserved state due to a misunderstanding of the difference between Reserved and Unallocated that went undetected for a long time. Additional allocations from the Reserved state are not expected, and the TLS SignatureScheme registry is suitable for use for new allocations instead of this registry.

IANA has added the following values to the "TLS Supported Groups" registry:

| Value | Description | DTLS-OK | Recommended | Reference |
|-------|-------------|---------|-------------|-----------|
| 34    | GC256A      | Y       | N           | RFC 9189  |
| 35    | GC256B      | Y       | N           | RFC 9189  |
| 36    | GC256C      | Y       | N           | RFC 9189  |
| 37    | GC256D      | Y       | N           | RFC 9189  |
| 38    | GC512A      | Y       | N           | RFC 9189  |



|    |        |   |   |          |
|----|--------|---|---|----------|
| 39 | GC512B | Y | N | RFC 9189 |
| 40 | GC512C | Y | N | RFC 9189 |

Table 7

IANA has added the following values to the "TLS ClientCertificateType Identifiers" registry:

| Value | Description  | DTLS-OK | Reference |
|-------|--------------|---------|-----------|
| 67    | gost_sign256 | Y       | RFC 9189  |
| 68    | gost_sign512 | Y       | RFC 9189  |

Table 8

## 10. Historical Considerations

Note that prior to the existence of this document, implementations could use only the values from the "Private Use" space in order to use the GOST-based algorithms. So some old implementations can still use the old value {0xFF, 0x85} instead of the {0xC1, 0x02} value to indicate the TLS GOSTR341112\_256\_WITH\_28147\_CNT\_IMIT cipher suite; the old value 0xEE instead of the values 64, 8, and 67 (to indicate the gostr34102012\_256 signature algorithm, the Intrinsic hash algorithm, and the gost\_sign256 certificate type, respectively); the old value 0xEF instead of the values 65, 8, and 68 (to indicate the gostr34102012\_512 signature algorithm, the Intrinsic hash algorithm, and the gost\_sign512 certificate type, respectively).

Due to historical reasons, in addition to the curve identifier values listed in Table 2, there exist some extra identifier values that correspond to the curves GC256B, GC256C, and GC256D as follows (see [RFC4357] and [R-1323565.1.024-2019]).

| Description | Curve Identifier Values                                                           |
|-------------|-----------------------------------------------------------------------------------|
| GC256B      | id-GostR3410_2001-CryptoPro-XchA-ParamSet<br>id-tc26-gost-3410-2012-256-paramSetB |
| GC256C      | id-tc26-gost-3410-2012-256-paramSetC                                              |
| GC256D      | id-GostR3410-2001-CryptoPro-XchB-ParamSet<br>id-tc26-gost-3410-2012-256-paramSetD |

Table 9

The client should be prepared to handle any of these correctly if the corresponding group is included in the supported\_groups extension

(see [RFC8422] and [RFC7919]).

## 11. Security Considerations

The cipher suites defined in this document do not provide Perfect Forward Secrecy.

The authenticate-then-encrypt method is crucial for the CNT\_IMIT cipher suite. Encryption of the MAC value is conducted to reduce the possibility of forgery to guessing. Here, the probability of a guess is approximately equal to  $2^{-32}$ , which is acceptable in some practical cases.

## 12. References

### 12.1. Normative References

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## Appendix A. Test Examples

### A.1. Test Examples for CTR\_OMAC Cipher Suites

#### A.1.1. TLSTREE Examples

##### A.1.1.1. TLS\_GOSTR341112\_256\_WITH\_MAGMA\_CTR\_OMAC Cipher Suite

TLS\_GOSTR341112\_256\_WITH\_MAGMA\_CTR\_OMAC  
\*\*\*\*\*  
Root Key K\_root:  
00 11 22 33 44 55 66 77 88 99 AA BB CC EE FF 0A  
11 22 33 44 55 66 77 88 99 AA BB CC EE FF 0A 00  
  
seqnum = 0

First-level key from Divers\_1:

F3 55 89 F0 9B F8 01 B1 CA 11 42 73 B9 5F D6 C1  
39 2E 78 F9 FB 81 4D A0 5A 7C CA 08 9E C8 65 42

Second-level key from Divers\_2:

51 37 D5 C4 A6 E6 BE 42 C4 40 D1 0A 95 EE A0 7F  
08 9E 74 0D 38 90 EB 52 65 2C 0C B9 3F 20 7B B4

The resulting key from Divers\_3:

19 A7 6E D3 0F 4D 6D 1F 5B 72 63 EC 49 1A D8 38  
17 C0 B5 7D 8A 03 56 12 71 40 FB 4F 74 25 49 4D

seqnum = 4095

First-level key from Divers\_1:

F3 55 89 F0 9B F8 01 B1 CA 11 42 73 B9 5F D6 C1  
39 2E 78 F9 FB 81 4D A0 5A 7C CA 08 9E C8 65 42

Second-level key from Divers\_2:

51 37 D5 C4 A6 E6 BE 42 C4 40 D1 0A 95 EE A0 7F  
08 9E 74 0D 38 90 EB 52 65 2C 0C B9 3F 20 7B B4

The resulting key from Divers\_3:

19 A7 6E D3 0F 4D 6D 1F 5B 72 63 EC 49 1A D8 38  
17 C0 B5 7D 8A 03 56 12 71 40 FB 4F 74 25 49 4D

seqnum = 4096

First-level key from Divers\_1:

F3 55 89 F0 9B F8 01 B1 CA 11 42 73 B9 5F D6 C1  
39 2E 78 F9 FB 81 4D A0 5A 7C CA 08 9E C8 65 42

Second-level key from Divers\_2:

51 37 D5 C4 A6 E6 BE 42 C4 40 D1 0A 95 EE A0 7F  
08 9E 74 0D 38 90 EB 52 65 2C 0C B9 3F 20 7B B4

The resulting key from Divers\_3:

FB 30 EE 53 CF CF 89 D7 48 FC 0C 72 EF 16 0B 8B  
53 CB BB FD 03 12 82 B0 26 21 4A B2 E0 77 58 FF

seqnum = 33554431

First-level key from Divers\_1:

F3 55 89 F0 9B F8 01 B1 CA 11 42 73 B9 5F D6 C1  
39 2E 78 F9 FB 81 4D A0 5A 7C CA 08 9E C8 65 42

Second-level key from Divers\_2:

51 37 D5 C4 A6 E6 BE 42 C4 40 D1 0A 95 EE A0 7F  
08 9E 74 0D 38 90 EB 52 65 2C 0C B9 3F 20 7B B4

The resulting key from Divers\_3:

B8 5B 36 DC 22 82 32 6B C0 35 C5 72 DC 93 F1 8D  
83 AA 01 74 F3 94 20 9A 51 3B B3 74 DC 09 35 AE

seqnum = 33554432

First-level key from Divers\_1:

F3 55 89 F0 9B F8 01 B1 CA 11 42 73 B9 5F D6 C1  
39 2E 78 F9 FB 81 4D A0 5A 7C CA 08 9E C8 65 42

Second-level key from Divers\_2:

3F EA 59 38 DA 2B F8 DD C4 7E C1 DC 55 61 89 66  
79 02 BE 42 0D F4 C3 7D AF 21 75 3B CB 1D C7 F3

The resulting key from Divers\_3:

0F D7 C0 9E FD F8 E8 15 73 EE CC F8 6E 4B 95 E3  
AF 7F 34 DA B1 17 7C FD 7D B9 7B 6D A9 06 40 8A

seqnum = 274877906943

First-level key from Divers\_1:

F3 55 89 F0 9B F8 01 B1 CA 11 42 73 B9 5F D6 C1  
39 2E 78 F9 FB 81 4D A0 5A 7C CA 08 9E C8 65 42

Second-level key from Divers\_2:

AB F3 A5 37 98 3A 1B 98 40 06 6D E6 8A 49 BF 25  
97 7E E5 C3 F5 2D 33 3E 3C 22 0F 1D 15 C5 08 93

The resulting key from Divers\_3:

48 0F 99 72 BA F2 5D 4C 36 9A 96 AF 91 BC A4 55  
3F 79 D8 F0 C5 61 8B 19 FD 44 CF DC 57 FA 37 33

seqnum = 274877906944

First-level key from Divers\_1:

15 60 0D 9E 8F A6 85 54 CF 15 2D C7 4F BC 42 51  
17 B0 3E 09 76 BB 28 EA 98 24 C3 B7 0F 28 CB D8

Second-level key from Divers\_2:

6C C2 8E B0 93 24 72 12 5C 7A D3 F8 09 73 B3 C8  
C4 13 7D A5 73 BC 17 1A 24 ED D4 A3 71 F1 F8 73

The resulting key from Divers\_3:

25 28 C1 C6 A8 F0 92 7B F2 BE 27 BB 78 D2 7F 21  
46 D6 55 93 B0 C7 17 3A 06 CB 9D 88 DF 92 32 65

#### A.1.1.2. TLS\_GOSTR341112\_256\_WITH\_KUZNYECHIK\_CTR\_OMAC Cipher Suite

TLS\_GOSTR341112\_256\_WITH\_KUZNYECHIK\_CTR\_OMAC

\*\*\*\*\*

Root Key K\_root:

00 11 22 33 44 55 66 77 88 99 AA BB CC EE FF 0A  
11 22 33 44 55 66 77 88 99 AA BB CC EE FF 0A 00

seqnum = 0

First-level key from Divers\_1:

F3 55 89 F0 9B F8 01 B1 CA 11 42 73 B9 5F D6 C1  
39 2E 78 F9 FB 81 4D A0 5A 7C CA 08 9E C8 65 42

Second-level key from Divers\_2:

51 37 D5 C4 A6 E6 BE 42 C4 40 D1 0A 95 EE A0 7F  
08 9E 74 0D 38 90 EB 52 65 2C 0C B9 3F 20 7B B4

The resulting key from Divers\_3:

19 A7 6E D3 0F 4D 6D 1F 5B 72 63 EC 49 1A D8 38  
17 C0 B5 7D 8A 03 56 12 71 40 FB 4F 74 25 49 4D

seqnum = 63

First-level key from Divers\_1:

F3 55 89 F0 9B F8 01 B1 CA 11 42 73 B9 5F D6 C1  
39 2E 78 F9 FB 81 4D A0 5A 7C CA 08 9E C8 65 42

Second-level key from Divers\_2:

51 37 D5 C4 A6 E6 BE 42 C4 40 D1 0A 95 EE A0 7F  
08 9E 74 0D 38 90 EB 52 65 2C 0C B9 3F 20 7B B4

The resulting key from Divers\_3:

19 A7 6E D3 0F 4D 6D 1F 5B 72 63 EC 49 1A D8 38  
17 C0 B5 7D 8A 03 56 12 71 40 FB 4F 74 25 49 4D

seqnum = 64

First-level key from Divers\_1:

F3 55 89 F0 9B F8 01 B1 CA 11 42 73 B9 5F D6 C1  
39 2E 78 F9 FB 81 4D A0 5A 7C CA 08 9E C8 65 42

Second-level key from Divers\_2:

51 37 D5 C4 A6 E6 BE 42 C4 40 D1 0A 95 EE A0 7F  
08 9E 74 0D 38 90 EB 52 65 2C 0C B9 3F 20 7B B4

The resulting key from Divers\_3:

AE BE 1E F4 18 71 3B F0 44 B9 FC D9 E5 72 D4 37  
FB 38 B5 D8 29 56 7A 6F 79 18 39 6D 9F 4E 09 6B

seqnum = 524287

First-level key from Divers\_1:

F3 55 89 F0 9B F8 01 B1 CA 11 42 73 B9 5F D6 C1  
39 2E 78 F9 FB 81 4D A0 5A 7C CA 08 9E C8 65 42

Second-level key from Divers\_2:

51 37 D5 C4 A6 E6 BE 42 C4 40 D1 0A 95 EE A0 7F  
08 9E 74 0D 38 90 EB 52 65 2C 0C B9 3F 20 7B B4

The resulting key from Divers\_3:

6F 18 D4 00 3E A2 CB 30 F5 FE C1 93 A2 34 F0 7D  
7C 43 94 98 7F 50 75 8D E2 2B 22 0D 8A 10 51 06

seqnum = 524288

First-level key from Divers\_1:

F3 55 89 F0 9B F8 01 B1 CA 11 42 73 B9 5F D6 C1  
39 2E 78 F9 FB 81 4D A0 5A 7C CA 08 9E C8 65 42

Second-level key from Divers\_2:

F6 59 EB 85 EE BD 2A 8D CC 1B B3 F7 C6 00 57 FF  
6D 33 B6 0F 74 65 DD 42 B5 11 2C F3 A6 B1 AB 66

The resulting key from Divers\_3:

E5 4B 16 41 5B 3B 66 3E 78 0B 06 2D 24 F7 36 C4  
49 54 63 C3 A8 91 E1 FA 46 F7 AE 99 FF F9 F3 78

seqnum = 4294967295

First-level key from Divers\_1:

F3 55 89 F0 9B F8 01 B1 CA 11 42 73 B9 5F D6 C1  
39 2E 78 F9 FB 81 4D A0 5A 7C CA 08 9E C8 65 42

Second-level key from Divers\_2:

F4 BC 10 1A BB 68 86 2A 8C E3 1E A0 0D DF A7 FE  
B8 29 10 F1 24 F4 B1 E2 9E A8 3B E0 06 C2 26 8D

The resulting key from Divers\_3:

CF 60 09 04 C7 1E 7B 88 A4 9A C8 E2 45 77 4B 3D  
BE ED FB 81 DE 9A 0E 2F 4E 46 C3 56 07 BC 2F 04

seqnum = 4294967296

First-level key from Divers\_1:

55 CC 95 E0 D1 FB 54 85 AF 8E F6 9A CD 72 B2 32  
79 7C D2 E8 5D 86 CD FD 1D E5 5B D1 FA 14 37 78

Second-level key from Divers\_2:

72 16 91 E1 01 C4 28 96 A6 40 AE 18 3F BB 44 5B  
76 37 9C 57 E1 FD 8A 7D 49 A6 23 E4 23 8C 0E 1D

The resulting key from Divers\_3:

16 18 0B 24 64 54 00 B8 36 14 38 37 D8 6A AC 93  
95 2A E3 EB 82 44 D5 EC 2A B0 2C FF 30 78 11 38

## A.1.2. Record Examples

### A.1.2.1. TLS\_GOSTR341112\_256\_WITH\_MAGMA\_CTR\_OMAC Cipher Suite

TLS\_GOSTR341112\_256\_WITH\_MAGMA\_CTR\_OMAC

\*\*\*\*\*

It is assumed that the following keys were established during handshake:

- MAC key:

00000: 00 11 22 33 44 55 66 77 88 99 AA BB CC EE FF 0A  
00010: 11 22 33 44 55 66 77 88 99 AA BB CC EE FF 0A 00

- Encryption key:

00000: 22 33 44 55 66 77 88 99 AA BB CC EE FF 0A 00 11  
00010: 33 44 55 66 77 88 99 AA BB CC EE FF 0A 00 11 22

- IV:

00000: 00 00 00 00

-----  
seqnum = 0

Application data:

00000: 00 00 00 00 00 00 00 00

TLSPlaintext:

00000: 17 03 03 00 07 00 00 00 00 00 00 00

K\_MAC\_0:

00000: 19 A7 6E D3 0F 4D 6D 1F 5B 72 63 EC 49 1A D8 38  
00010: 17 C0 B5 7D 8A 03 56 12 71 40 FB 4F 74 25 49 4D

MAC value:

00000: F3 3E B6 89 6F EC E2 86

K\_ENC\_0:

00000: 58 AF BE 9A 4C 31 98 AA AB AA 26 92 C4 19 F1 79



00010: 7C 9B 92 DE B3 CC 74 46 B3 63 57 71 13 F0 FB 56

IV\_0:

00000: 00 00 00 00

TLSCiphertext:

00000: 17 03 03 00 0F 9B 42 0D A8 6F AF 36 7F 05 14 43

00010: CE 9C 10 72

-----  
seqnum = 4095

Application data:

00000: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00

00010: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00

00020: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00

003D0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00

003E0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00

003F0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00

TLSPaintext:

00000: 17 03 03 04 00 00 00 00 00 00 00 00 00 00 00 00

00010: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00

00020: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00

003D0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00

003E0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00

003F0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00

00400: 00 00 00 00 00

K\_MAC\_4095:

00000: 19 A7 6E D3 0F 4D 6D 1F 5B 72 63 EC 49 1A D8 38

00010: 17 C0 B5 7D 8A 03 56 12 71 40 FB 4F 74 25 49 4D

MAC value:

00000: 58 D3 BB 60 8F BC 98 B8

K\_ENC\_4095:

00000: 58 AF BE 9A 4C 31 98 AA AB AA 26 92 C4 19 F1 79

00010: 7C 9B 92 DE B3 CC 74 46 B3 63 57 71 13 F0 FB 56

IV\_4095:

00000: 00 00 0F FF

TLSCiphertext:

00000: 17 03 03 04 08 B7 11 43 8B 16 20 1F 3C 49 33 95

00010: 21 C9 C8 CA 75 66 D4 C2 0F D3 3E 58 1F 80 07 DC

00020: 76 04 3E 2B 35 C8 E8 4B B2 55 08 27 66 13 59 6F

003D0: E7 77 70 BF 45 17 E1 F8 DD 1B 2C 05 64 AD 68 FC

003E0: 4A 88 9A 48 B8 B1 FF 0E A4 E1 BB 70 4D 56 A4 75

003F0: 2F 51 A5 82 CC 54 1A 80 8F 8C 8B 62 97 68 88 C8

00400: 10 59 DE 41 27 63 A3 E0 99 9A CD DA 77

-----  
seqnum = 4096

**Application data:**

00000: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  
00010: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  
00020: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00

007D0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  
007E0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  
007F0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00

**TLSPlaintext:**

00000: 17 03 03 08 00 00 00 00 00 00 00 00 00 00 00 00  
00010: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  
00020: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00

007D0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  
007E0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  
007F0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  
00800: 00 00 00 00 00

**K\_MAC\_4096:**

00000: FB 30 EE 53 CF CF 89 D7 48 FC 0C 72 EF 16 0B 8B  
00010: 53 CB BB FD 03 12 82 B0 26 21 4A B2 E0 77 58 FF

**MAC value:**

00000: 50 55 A2 6A BE 19 63 81

**K\_ENC\_4096:**

00000: ED F2 FD 02 47 71 60 23 83 09 00 2D 1D 57 DF 9F  
00010: D2 ED 18 D6 45 66 C7 6F 4B F0 3D 3A BF 7B BB 1E

**IV\_4096:**

00000: 00 00 10 00

**TLSCiphertext:**

00000: 17 03 03 08 08 99 95 26 07 03 47 1D ED A2 E6 55  
00010: B6 B3 93 83 5E 33 8B 1E D0 0E DD 22 47 A2 FB 88  
00020: FB B7 A8 94 80 62 08 8A F3 2C AE B6 AA 2C 4F 2A

007D0: 7F 0B 24 61 E7 5F E1 06 34 B8 4D C5 70 35 72 5A  
007E0: CA 4F 0C BC A9 B0 6C B9 F7 6F BD 2F 80 46 2B 8D  
007F0: 77 5E BD 41 6F 63 41 39 AC 89 C2 ED 3D F1 9F E2  
00800: 4E F8 C0 5A A8 90 93 1B 01 86 FD 7D DF

**A.1.2.2. TLS\_GOSTR341112\_256\_WITH\_KUZNYECHIK\_CTR\_OMAC Cipher Suite**

**TLS\_GOSTR341112\_256\_WITH\_KUZNYECHIK\_CTR\_OMAC**

\*\*\*\*\*

It is assumed that the following keys were established during handshake:

**- MAC key:**

00000: 00 11 22 33 44 55 66 77 88 99 AA BB CC EE FF 0A  
00010: 11 22 33 44 55 66 77 88 99 AA BB CC EE FF 0A 00

**- Encryption key:**

00000: 22 33 44 55 66 77 88 99 AA BB CC EE FF 0A 00 11

00010: 33 44 55 66 77 88 99 AA BB CC EE FF 0A 00 11 22  
- IV:  
00000: 00 00 00 00 00 00 00 00 00

-----  
seqnum = 0

Application data:

00000: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00

TLSPplaintext:

00000: 17 03 03 00 0F 00 00 00 00 00 00 00 00 00 00 00  
00010: 00 00 00 00

K\_MAC\_0:

00000: 19 A7 6E D3 0F 4D 6D 1F 5B 72 63 EC 49 1A D8 38  
00010: 17 C0 B5 7D 8A 03 56 12 71 40 FB 4F 74 25 49 4D

MAC value:

00000: FD 17 19 DD 95 08 37 EB 7C 7B B8 F5 00 37 99 81

K\_ENC\_0:

00000: 58 AF BE 9A 4C 31 98 AA AB AA 26 92 C4 19 F1 79  
00010: 7C 9B 92 DE B3 CC 74 46 B3 63 57 71 13 F0 FB 56

IV\_0:

00000: 00 00 00 00 00 00 00 00 00

TLSCiphertext:

00000: 17 03 03 00 1F 4D 1A 30 52 36 57 3B FF C1 4E 46  
00010: DC BE 74 6D B6 C9 9A 17 5A 81 C4 71 1E 2F 84 C3  
00020: 92 C5 40 7C

-----  
seqnum = 63

Application data:

00000: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  
00010: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  
00020: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00

00FD0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  
00FE0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  
00FF0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00

TLSPplaintext:

00000: 17 03 03 10 00 00 00 00 00 00 00 00 00 00 00 00  
00010: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  
00020: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00

00FD0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  
00FE0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  
00FF0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  
01000: 00 00 00 00 00

K\_MAC\_63:

00000: 19 A7 6E D3 0F 4D 6D 1F 5B 72 63 EC 49 1A D8 38  
00010: 17 C0 B5 7D 8A 03 56 12 71 40 FB 4F 74 25 49 4D

MAC value:

00000: 98 46 27 61 D0 26 24 4A 2C 0B 7D 1B CC CB E7 B0

K\_ENC\_63:

00000: 58 AF BE 9A 4C 31 98 AA AB AA 26 92 C4 19 F1 79

00010: 7C 9B 92 DE B3 CC 74 46 B3 63 57 71 13 F0 FB 56

IV\_63:

00000: 00 00 00 00 00 00 00 00 3F

TLSCiphertext:

00000: 17 03 03 10 10 12 93 51 D2 6E 14 07 13 A2 1B 37

00010: 68 24 A2 23 17 CD C0 D8 8E 01 CF A3 FE 21 41 5F

00020: 5C 5E 05 86 9C CF 38 A5 1B C2 E0 ED 68 94 46 A8

00FE0: 19 AD 99 8C 06 25 21 E6 7B 63 59 A4 F5 C8 16 F9

00FF0: 47 6B A7 13 26 82 BB A8 CE 0B ED AD 65 E4 20 A2

01000: 97 B6 E2 C6 1F A4 06 D9 B8 CA 36 FD 9F CD 3A EE

01010: 24 78 F4 D1 96

-----  
seqnum = 64

Application data:

00000: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00

00010: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00

00020: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00

01FD0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00

01FE0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00

01FF0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00

TLSPlaintext:

00000: 17 03 03 20 00 00 00 00 00 00 00 00 00 00 00 00

00010: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00

00020: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00

01FD0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00

01FE0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00

01FF0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00

02000: 00 00 00 00 00

K\_MAC\_64:

00000: AE BE 1E F4 18 71 3B F0 44 B9 FC D9 E5 72 D4 37

00010: FB 38 B5 D8 29 56 7A 6F 79 18 39 6D 9F 4E 09 6B

MAC value:

00000: EA C3 97 87 84 2B 1D BD 60 80 CC 3F BF AE 5C 2F

K\_ENC\_64:

00000: 64 F5 5A FC 37 A1 74 D9 53 3E 70 8B CD 14 FA 4A

00010: EE C3 7B C0 E3 2B A4 99 01 B4 66 9E 96 A6 3D 96

```

IV_64:
00000: 00 00 00 00 00 00 00 00 40

TLSCiphertext:
00000: 17 03 03 20 10 E6 66 BB 98 AC 5B 0F 39 31 D8 55
00010: 1B 93 36 85 96 EE F0 EB A8 26 9C B8 BD AA E7 EB
00020: 80 C8 30 D7 5A B7 D4 6C 25 06 DC 8B 83 E1 F2 D3

01FE0: B3 02 67 2C CB 02 86 CD 40 48 FB D5 38 1A 65 55
01FF0: 26 11 25 51 01 4F A8 ED F5 C2 1B 7D 1D B3 9D 6B
02000: AD EC 0D 7C 07 05 34 8B 5C 55 6C 4D 50 81 69 1A
02010: A9 EC 36 F8 B5

```

### A.1.3. Handshake Examples

The ClientHello.extensions and the ServerHello.extensions fields contain the extended\_main\_secret extension (see [RFC7627]) and the renegotiation\_info extension (see [RFC5746]) in the following examples.

#### A.1.3.1. TLS\_GOSTR341112\_256\_WITH\_MAGMA\_CTR\_OMAC Cipher Suite

Server certificate curve OID:  
id-GostR3410-2001-CryptoPro-A-ParamSet, "1.2.643.2.2.35.1"

Server public key Q\_s:  
x = 0x6531D4A72E655BF9C9DFB94293B260702  
82FABF10D5C49B7366148C60E0BF8167

y = 0x37F8CC71DC5D917FC4A66F7826E72750  
8270B4FFC266C26CD4363E77B553A5B8

Server private key d\_s:  
0x5F308355DFD6A8ACAE0837B100A3B1F  
6D63FB29B78EF27D3967757F0527144C

-----Client-----

ClientHello message:

```

msg_type: 01
length: 000040
body:
 client_version:
 major: 03
 minor: 03
 random: 933EA21EC3802A561550EC78D6ED51AC
 2439D7E749C31BC3A3456165889684CA
 session_id:
 length: 00
 vector: --
 cipher_suites:
 length: 0004
 vector:
 CipherSuite: C100

```

```

 CipherSuite: C101
compression_methods:
 length: 01
 vector:
 CompressionMethod: 00
extensions:
 length: 0013
 vector:
 Extension: /* signature_algorithms */
 extension_type: 000D
 extension_data:
 length: 0006
 vector:
 supported_signature_algorithms:
 length: 0004
 vector:
 /* 1 pair of algorithms */
 hash: 08
 signature:
 40
 /* 2 pair of algorithms */
 hash: 08
 signature:
 41
 Extension: /* renegotiation_info */
 extension_type: FF01
 extension_data:
 length: 0001
 vector:
 renegotiated_connection:
 length: 00
 vector: --
 Extension: /* extended_main_secret */
 extension_type: 0017
 extension_data:
 length: 0000
 vector: --

```

```

00000: 01 00 00 40 03 03 93 3E A2 1E C3 80 2A 56 15 50
00010: EC 78 D6 ED 51 AC 24 39 D7 E7 49 C3 1B C3 A3 45
00020: 61 65 88 96 84 CA 00 00 04 C1 00 C1 01 01 00 00
00030: 13 00 0D 00 06 00 04 08 40 08 41 FF 01 00 01 00
00040: 00 17 00 00

```

Record layer message:

```

type: 16
version:
 major: 03
 minor: 03
length: 0044
fragment: 010000400303933EA21EC3802A561550
 EC78D6ED51AC2439D7E749C31BC3A345
 6165889684CA000004C100C101010000
 13000D0006000408400841FF01000100
 00170000

```

```
00000: 16 03 03 00 44 01 00 00 40 03 03 93 3E A2 1E C3
00010: 80 2A 56 15 50 EC 78 D6 ED 51 AC 24 39 D7 E7 49
00020: C3 1B C3 A3 45 61 65 88 96 84 CA 00 00 04 C1 00
00030: C1 01 01 00 00 13 00 0D 00 06 00 04 08 40 08 41
00040: FF 01 00 01 00 00 17 00 00
```

-----Server-----

ServerHello message:

```
msg_type: 02
length: 000041
body:
 server_version:
 major: 03
 minor: 03
 random: 933EA21E49C31BC3A3456165889684CA
 A5576CE7924A24F58113808DBD9EF856
 session_id:
 length: 10
 vector: C3802A561550EC78D6ED51AC2439D7E7
 cipher_suite:
 CipherSuite: C101
 compression_method:
 CompressionMethod: 00
 extensions:
 length: 0009
 vector:
 Extension: /* renegotiation_info */
 extension_type: FF01
 extension_data:
 length: 0001
 vector:
 renegotiated_connection:
 length: 00
 vector: --
 Extension: /* extended_main_secret */
 extension_type: 0017
 extension_data:
 length: 0000
 vector: --
```

```
00000: 02 00 00 41 03 03 93 3E A2 1E 49 C3 1B C3 A3 45
00010: 61 65 88 96 84 CA A5 57 6C E7 92 4A 24 F5 81 13
00020: 80 8D BD 9E F8 56 10 C3 80 2A 56 15 50 EC 78 D6
00030: ED 51 AC 24 39 D7 E7 C1 01 00 00 09 FF 01 00 01
00040: 00 00 17 00 00
```

Record layer message:

```
type: 16
version:
 major: 03
 minor: 03
length: 0045
fragment: 020000410303933EA21E49C31BC3A345
 6165889684CAA5576CE7924A24F58113
```

808DBD9EF85610C3802A561550EC78D6  
ED51AC2439D7E7C101000009FF010001  
0000170000

00000: 16 03 03 00 45 02 00 00 41 03 03 93 3E A2 1E 49  
00010: C3 1B C3 A3 45 61 65 88 96 84 CA A5 57 6C E7 92  
00020: 4A 24 F5 81 13 80 8D BD 9E F8 56 10 C3 80 2A 56  
00030: 15 50 EC 78 D6 ED 51 AC 24 39 D7 E7 C1 01 00 00  
00040: 09 FF 01 00 01 00 00 17 00 00

-----Server-----

Certificate message:

msg\_type: 0B

length: 0001DB

body:

certificate\_list:

length: 0001D8

vector:

ASN.1Cert:

length: 0001D5

vector: 308201D13082017EA003020102020833  
FBB2C0E9575A46300A06082A85030701  
010302301F311D301B06035504030C14

797990E4B5452CF82FE1F19EE237B754  
CBCD5078D752A28013DFFC8224AD114B  
BD7C1BB71E480AD6EEF9857A8C99C595  
9053EEDFE9

00000: 0B 00 01 DB 00 01 D8 00 01 D5 30 82 01 D1 30 82  
00010: 01 7E A0 03 02 01 02 02 08 33 FB B2 C0 E9 57 5A  
00020: 46 30 0A 06 08 2A 85 03 07 01 01 03 02 30 1F 31  
00030: 1D 30 1B 06 03 55 04 03 0C 14 74 65 73 74 5F 73  
00040: 65 6C 66 73 69 67 6E 65 64 5F 63 65 72 74 30 1E  
00050: 17 0D 31 39 30 36 32 37 31 35 32 34 30 38 5A 17  
00060: 0D 32 30 31 32 31 38 31 35 33 34 30 38 5A 30 1F  
00070: 31 1D 30 1B 06 03 55 04 03 0C 14 74 65 73 74 5F  
00080: 73 65 6C 66 73 69 67 6E 65 64 5F 63 65 72 74 30  
00090: 66 30 1F 06 08 2A 85 03 07 01 01 01 01 30 13 06  
000A0: 07 2A 85 03 02 02 23 01 06 08 2A 85 03 07 01 01  
000B0: 02 02 03 43 00 04 40 67 81 BF E0 60 8C 14 66 73  
000C0: 9B C4 D5 10 BF FA 82 02 07 26 3B 29 94 FB 9D FC  
000D0: 5B 65 2E A7 D4 31 65 B8 A5 53 B5 77 3E 36 D4 6C  
000E0: C2 66 C2 FF B4 70 82 50 27 E7 26 78 6F A6 C4 7F  
000F0: 91 5D DC 71 CC F8 37 A3 81 96 30 81 93 30 1D 06  
00100: 03 55 1D 0E 04 16 04 14 E7 D0 0B B8 4D 8D 24 18  
00110: 29 3E 05 C1 7C E7 77 98 D4 8D 30 16 30 0E 06 03  
00120: 55 1D 0F 01 01 FF 04 04 03 02 01 C6 30 12 06 03  
00130: 55 1D 13 01 01 FF 04 08 30 06 01 01 FF 02 01 01  
00140: 30 4E 06 03 55 1D 23 04 47 30 45 80 14 E7 D0 0B  
00150: B8 4D 8D 24 18 29 3E 05 C1 7C E7 77 98 D4 8D 30  
00160: 16 A1 23 A4 21 30 1F 31 1D 30 1B 06 03 55 04 03  
00170: 0C 14 74 65 73 74 5F 73 65 6C 66 73 69 67 6E 65  
00180: 64 5F 63 65 72 74 82 08 33 FB B2 C0 E9 57 5A 46



00190: 30 0A 06 08 2A 85 03 07 01 01 03 02 03 41 00 E2  
001A0: 88 44 F9 F1 C8 55 E2 DB 5B 19 79 79 90 E4 B5 45  
001B0: 2C F8 2F E1 F1 9E E2 37 B7 54 CB CD 50 78 D7 52  
001C0: A2 80 13 DF FC 82 24 AD 11 4B BD 7C 1B B7 1E 48  
001D0: 0A D6 EE F9 85 7A 8C 99 C5 95 90 53 EE DF E9

Record layer message:

type: 16  
version:  
  major: 03  
  minor: 03  
length: 01DF  
fragment: 0B0001DB0001D80001D5308201D13082  
017EA003020102020833FBB2C0E9575A  
46300A06082A85030701010302301F31

8844F9F1C855E2DB5B19797990E4B545  
2CF82FE1F19EE237B754CBCD5078D752  
A28013DFFC8224AD114BBD7C1BB71E48  
0AD6EEF9857A8C99C5959053EEDFE9

00000: 16 03 03 01 DF 0B 00 01 DB 00 01 D8 00 01 D5 30  
00010: 82 01 D1 30 82 01 7E A0 03 02 01 02 02 08 33 FB  
00020: B2 C0 E9 57 5A 46 30 0A 06 08 2A 85 03 07 01 01  
00030: 03 02 30 1F 31 1D 30 1B 06 03 55 04 03 0C 14 74  
00040: 65 73 74 5F 73 65 6C 66 73 69 67 6E 65 64 5F 63  
00050: 65 72 74 30 1E 17 0D 31 39 30 36 32 37 31 35 32  
00060: 34 30 38 5A 17 0D 32 30 31 32 31 38 31 35 33 34  
00070: 30 38 5A 30 1F 31 1D 30 1B 06 03 55 04 03 0C 14  
00080: 74 65 73 74 5F 73 65 6C 66 73 69 67 6E 65 64 5F  
00090: 63 65 72 74 30 66 30 1F 06 08 2A 85 03 07 01 01  
000A0: 01 01 30 13 06 07 2A 85 03 02 02 23 01 06 08 2A  
000B0: 85 03 07 01 01 02 02 03 43 00 04 40 67 81 BF E0  
000C0: 60 8C 14 66 73 9B C4 D5 10 BF FA 82 02 07 26 3B  
000D0: 29 94 FB 9D FC 5B 65 2E A7 D4 31 65 B8 A5 53 B5  
000E0: 77 3E 36 D4 6C C2 66 C2 FF B4 70 82 50 27 E7 26  
000F0: 78 6F A6 C4 7F 91 5D DC 71 CC F8 37 A3 81 96 30  
00100: 81 93 30 1D 06 03 55 1D 0E 04 16 04 14 E7 D0 0B  
00110: B8 4D 8D 24 18 29 3E 05 C1 7C E7 77 98 D4 8D 30  
00120: 16 30 0E 06 03 55 1D 0F 01 01 FF 04 04 03 02 01  
00130: C6 30 12 06 03 55 1D 13 01 01 FF 04 08 30 06 01  
00140: 01 FF 02 01 01 30 4E 06 03 55 1D 23 04 47 30 45  
00150: 80 14 E7 D0 0B B8 4D 8D 24 18 29 3E 05 C1 7C E7  
00160: 77 98 D4 8D 30 16 A1 23 A4 21 30 1F 31 1D 30 1B  
00170: 06 03 55 04 03 0C 14 74 65 73 74 5F 73 65 6C 66  
00180: 73 69 67 6E 65 64 5F 63 65 72 74 82 08 33 FB B2  
00190: C0 E9 57 5A 46 30 0A 06 08 2A 85 03 07 01 01 03  
001A0: 02 03 41 00 E2 88 44 F9 F1 C8 55 E2 DB 5B 19 79  
001B0: 79 90 E4 B5 45 2C F8 2F E1 F1 9E E2 37 B7 54 CB  
001C0: CD 50 78 D7 52 A2 80 13 DF FC 82 24 AD 11 4B BD  
001D0: 7C 1B B7 1E 48 0A D6 EE F9 85 7A 8C 99 C5 95 90  
001E0: 53 EE DF E9

-----Server-----

ServerHelloDone message:

msg\_type: 0E  
length: 000000  
body: --

00000: 0E 00 00 00

Record layer message::

type: 16  
version:  
  major: 03  
  minor: 03  
length: 0004  
fragment: 0E000000

00000: 16 03 03 00 04 0E 00 00 00

-----Client-----

PMS:

00000: A5 57 6C E7 92 4A 24 F5 81 13 80 8D BD 9E F8 56  
00010: F5 BD C3 B1 83 CE 5D AD CA 36 A5 3A A0 77 65 1D

Random d\_eph value:

0xA5C77C7482373DE16CE4A6F73CCE7F78  
471493FF2C0709B8B706C9E8A25E6C1E

Q\_eph ephemeral key:

x = 0xA8F36D63D262A203978F1B3B6795CDBB  
F1AE7FB8EF7F47F1F18871C198E00793

y = 0x34CA5D6B4485640EA195435993BEB1F8  
B016ED610496B5CC175AC2EA1F14F887

HASH (r\_c | r\_s):

00000: C3 EF 04 28 D4 B7 A1 F4 C5 02 5F 2E 65 DD 2B 2E  
00010: A5 83 AE EF DB 67 C7 F4 21 4A 6A 29 8E 99 E3 25

Export key generation. r value:

0xC3EF0428D4B7A1F4C5025F2E65DD2B2E

Export key generation. UKM value:

0xC3EF0428D4B7A1F4C5025F2E65DD2B2E

seed:

00000: A5 83 AE EF DB 67 C7 F4

K\_EXP:

00000: 1E 58 54 90 E8 65 FF D1 8F 18 D7 C0 A0 4D 0E E8  
00010: 4F 1A 5D 79 7C EF AD A0 1B 1E 3B 7F DB 90 E0 29

Export keys K\_Exp\_MAC | K\_Exp\_ENC used in KExp15 algorithm:

00000: 2D 8B A8 C8 4C B2 32 FF 41 F1 0C 3A D9 24 13 42  
00010: 23 25 4F 71 E5 69 6D 3D 29 C3 E4 C9 DA A6 B2 93  
00020: 84 9E B6 34 0B FF AE 69 28 A3 C3 E4 FF 92 EC CB

00030: 1E 8F 0C F7 A1 88 36 8E 6B 74 8E 52 EA 37 8B 0C

IV:

00000: 21 4A 6A 29

PMSEXP:

00000: D7 F0 F0 42 23 67 86 7B 25 FA 42 33 A9 54 F5 8B

00010: DE 92 E9 C9 BB FB 88 16 C9 9F 15 E6 39 87 22 A0

00020: B2 B7 BF E8 49 3E 9A 5C

-----Client-----

ClientKeyExchange message:

msg\_type: 10

length: 000095

body:

exchange\_keys: 3081920428D7F0F0422367867B25FA42  
33A954F58BDE92E9C9BBFB8816C99F15  
E6398722A0B2B7BFE8493E9A5C306630

EFB87FAEF1BBCD95673B1B8F9703A262  
D2636DF3A887F8141FEAC25A17CCB596  
0461ED16B0F8B1BE93594395A10E6485  
446B5DCA34

00000: 10 00 00 95 30 81 92 04 28 D7 F0 F0 42 23 67 86

00010: 7B 25 FA 42 33 A9 54 F5 8B DE 92 E9 C9 BB FB 88

00020: 16 C9 9F 15 E6 39 87 22 A0 B2 B7 BF E8 49 3E 9A

00030: 5C 30 66 30 1F 06 08 2A 85 03 07 01 01 01 01 30

00040: 13 06 07 2A 85 03 02 02 23 01 06 08 2A 85 03 07

00050: 01 01 02 02 03 43 00 04 40 93 07 E0 98 C1 71 88

00060: F1 F1 47 7F EF B8 7F AE F1 BB CD 95 67 3B 1B 8F

00070: 97 03 A2 62 D2 63 6D F3 A8 87 F8 14 1F EA C2 5A

00080: 17 CC B5 96 04 61 ED 16 B0 F8 B1 BE 93 59 43 95

00090: A1 0E 64 85 44 6B 5D CA 34

Record layer message:

type: 16

version:

major: 03

minor: 03

length: 0099

fragment: 100000953081920428D7F0F042236786  
7B25FA4233A954F58BDE92E9C9BBFB88  
16C99F15E6398722A0B2B7BFE8493E9A

F1F1477FEFB87FAEF1BBCD95673B1B8F  
9703A262D2636DF3A887F8141FEAC25A  
17CCB5960461ED16B0F8B1BE93594395  
A10E6485446B5DCA34

00000: 16 03 03 00 99 10 00 00 95 30 81 92 04 28 D7 F0

00010: F0 42 23 67 86 7B 25 FA 42 33 A9 54 F5 8B DE 92

00020: E9 C9 BB FB 88 16 C9 9F 15 E6 39 87 22 A0 B2 B7

00030: BF E8 49 3E 9A 5C 30 66 30 1F 06 08 2A 85 03 07

00040: 01 01 01 01 30 13 06 07 2A 85 03 02 02 23 01 06  
00050: 08 2A 85 03 07 01 01 02 02 03 43 00 04 40 93 07  
00060: E0 98 C1 71 88 F1 F1 47 7F EF B8 7F AE F1 BB CD  
00070: 95 67 3B 1B 8F 97 03 A2 62 D2 63 6D F3 A8 87 F8  
00080: 14 1F EA C2 5A 17 CC B5 96 04 61 ED 16 B0 F8 B1  
00090: BE 93 59 43 95 A1 0E 64 85 44 6B 5D CA 34

-----Server-----

PMSEXP extracted:

00000: D7 F0 F0 42 23 67 86 7B 25 FA 42 33 A9 54 F5 8B  
00010: DE 92 E9 C9 BB FB 88 16 C9 9F 15 E6 39 87 22 A0  
00020: B2 B7 BF E8 49 3E 9A 5C

HASH(r\_c | r\_s):

00000: C3 EF 04 28 D4 B7 A1 F4 C5 02 5F 2E 65 DD 2B 2E  
00010: A5 83 AE EF DB 67 C7 F4 21 4A 6A 29 8E 99 E3 25

Export key generation. r value:

0xC3EF0428D4B7A1F4C5025F2E65DD2B2E

Export key generation. UKM value:

0xC3EF0428D4B7A1F4C5025F2E65DD2B2E

seed:

00000: A5 83 AE EF DB 67 C7 F4

K\_EXP:

00000: 1E 58 54 90 E8 65 FF D1 8F 18 D7 C0 A0 4D 0E E8  
00010: 4F 1A 5D 79 7C EF AD A0 1B 1E 3B 7F DB 90 E0 29

Import keys K\_Imp\_MAC | K\_Imp\_ENC used in KImp15 algorithm:

00000: 2D 8B A8 C8 4C B2 32 FF 41 F1 0C 3A D9 24 13 42  
00010: 23 25 4F 71 E5 69 6D 3D 29 C3 E4 C9 DA A6 B2 93  
00020: 84 9E B6 34 0B FF AE 69 28 A3 C3 E4 FF 92 EC CB  
00030: 1E 8F 0C F7 A1 88 36 8E 6B 74 8E 52 EA 37 8B 0C

IV:

00000: 21 4A 6A 29

PMS:

00000: A5 57 6C E7 92 4A 24 F5 81 13 80 8D BD 9E F8 56  
00010: F5 BD C3 B1 83 CE 5D AD CA 36 A5 3A A0 77 65 1D

-----Client-----

HASH(HM):

00000: 7E 1F 59 D3 64 9D B6 09 00 EA 4F 8A 58 5A 65 7A  
00010: 92 77 B3 04 50 58 4C F5 43 51 19 8C DE A3 0C 49

MS:

00000: FD D2 7C B4 04 AD 4E 44 49 68 4F 7C 55 90 E9 E7  
00010: 02 EF 41 01 93 3B 52 77 A4 A9 6D F5 00 B0 7C C3  
00020: 32 4F D8 A6 D9 07 CB B0 3D F3 FB 33 1F 1C 4D 0C

Client connection key material

K\_write\_MAC|K\_read\_MAC|K\_write\_ENC|K\_read\_ENC|IV\_write|IV\_read:

00000: DD 4E 10 17 E3 09 1F FD 86 75 65 8A 78 00 90 09  
00010: 3B BE 69 EC A6 93 31 5C A8 5B E0 A6 14 3D C9 F8  
00020: 1D 64 D0 23 46 5F 8B EA 17 F8 12 F8 C2 D8 BF C0  
00030: D9 BB AB A7 B4 DF D3 A1 7C E0 E1 3B 2D 63 65 F3  
00040: FC 8B 34 59 CF 54 FE 44 9A 04 07 64 53 73 08 00  
00050: 75 10 32 55 9D 07 B6 C4 EA C6 75 48 71 BC 97 8A  
00060: B9 0E 2A EE 98 77 14 BB D8 F7 57 AE F7 84 FF 24  
00070: 47 B3 94 2E B4 3E 26 35 73 1C 4C 28 22 D0 2D 79  
00080: 2B 6A 81 3F 93 ED A6 FA

-----Server-----

HASH(HM):

00000: 7E 1F 59 D3 64 9D B6 09 00 EA 4F 8A 58 5A 65 7A  
00010: 92 77 B3 04 50 58 4C F5 43 51 19 8C DE A3 0C 49

MS:

00000: FD D2 7C B4 04 AD 4E 44 49 68 4F 7C 55 90 E9 E7  
00010: 02 EF 41 01 93 3B 52 77 A4 A9 6D F5 00 B0 7C C3  
00020: 32 4F D8 A6 D9 07 CB B0 3D F3 FB 33 1F 1C 4D 0C

Server connection key material

K\_read\_MAC|K\_write\_MAC|K\_read\_ENC|K\_write\_ENC|IV\_read|IV\_write:

00000: DD 4E 10 17 E3 09 1F FD 86 75 65 8A 78 00 90 09  
00010: 3B BE 69 EC A6 93 31 5C A8 5B E0 A6 14 3D C9 F8  
00020: 1D 64 D0 23 46 5F 8B EA 17 F8 12 F8 C2 D8 BF C0  
00030: D9 BB AB A7 B4 DF D3 A1 7C E0 E1 3B 2D 63 65 F3  
00040: FC 8B 34 59 CF 54 FE 44 9A 04 07 64 53 73 08 00  
00050: 75 10 32 55 9D 07 B6 C4 EA C6 75 48 71 BC 97 8A  
00060: B9 0E 2A EE 98 77 14 BB D8 F7 57 AE F7 84 FF 24  
00070: 47 B3 94 2E B4 3E 26 35 73 1C 4C 28 22 D0 2D 79  
00080: 2B 6A 81 3F 93 ED A6 FA

-----Client-----

ChangeCipherSpec message:

type: 01

00000: 01

Record layer message:

type: 14

version:

major: 03

minor: 03

length: 0001

fragment: 01

00000: 14 03 03 00 01 01

-----Client-----

HASH(HM):

00000: 7E 1F 59 D3 64 9D B6 09 00 EA 4F 8A 58 5A 65 7A  
00010: 92 77 B3 04 50 58 4C F5 43 51 19 8C DE A3 0C 49

client\_verify\_data:

00000: B4 61 C5 AD 25 EA 1E 62 B3 70 BD 1F 1B CB 16 91  
00010: FC CC BA 37 8B BC 13 43 BE 54 B3 8D F5 53 B7 A5

-----Client-----

Finished message:

msg\_type: 14  
length: 000020  
body:

verify\_data: B461C5AD25EA1E62B370BD1F1BCB1691  
FCCCB378BBC1343BE54B38DF553B7A5

00000: 14 00 00 20 B4 61 C5 AD 25 EA 1E 62 B3 70 BD 1F  
00010: 1B CB 16 91 FC CC BA 37 8B BC 13 43 BE 54 B3 8D  
00020: F5 53 B7 A5

Record layer message:

type: 16  
version:  
major: 03  
minor: 03  
length: 002C  
fragment: 0C630271D4DA39DD8D6BD040302D9B8F  
33D5F7B967EED155F7D65592892C03C7  
885C249B1225B184AB4D5DBF

00000: 16 03 03 00 2C 0C 63 02 71 D4 DA 39 DD 8D 6B D0  
00010: 40 30 2D 9B 8F 33 D5 F7 B9 67 EE D1 55 F7 D6 55  
00020: 92 89 2C 03 C7 88 5C 24 9B 12 25 B1 84 AB 4D 5D  
00030: BF

-----Server-----

ChangeCipherSpec message:

type: 01

00000: 01

Record layer message:

type: 14  
version:  
major: 03  
minor: 03  
length: 0001  
fragment: 01

00000: 14 03 03 00 01 01

-----Server-----

HASH(HM):

00000: DB D7 D8 93 82 4A ED FD D5 FB 7B 75 4B 47 E1 E6  
00010: AF E0 77 DA E6 D1 13 63 42 07 C7 EE 0F C6 F3 B1

server\_verify\_data:

00000: 45 39 EC 8D 0A F7 B1 A6 20 41 AB 43 4A 43 77 71  
00010: D3 4C 47 19 D8 6E BB FD 0F 28 C3 E9 53 55 0C D0

-----Server-----

Finished message:

msg\_type: 14  
length: 000020  
body:  
verify\_data: 4539EC8D0AF7B1A62041AB434A437771  
D34C4719D86EBBFD0F28C3E953550CD0

00000: 14 00 00 20 45 39 EC 8D 0A F7 B1 A6 20 41 AB 43  
00010: 4A 43 77 71 D3 4C 47 19 D8 6E BB FD 0F 28 C3 E9  
00020: 53 55 0C D0

Record layer message:

type: 16  
version:  
major: 03  
minor: 03  
length: 002C  
fragment: E6A94A4BF70886566A2316811E57B483  
BB1E47950A1FF820A80DCA77A4DF9954  
2DAB6953F3ED03D95CCA4748

00000: 16 03 03 00 2C E6 A9 4A 4B F7 08 86 56 6A 23 16  
00010: 81 1E 57 B4 83 BB 1E 47 95 0A 1F F8 20 A8 0D CA  
00020: 77 A4 DF 99 54 2D AB 69 53 F3 ED 03 D9 5C CA 47  
00030: 48

-----Client-----

Application data:

00000: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  
00010: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00

Record layer message:

type: 17  
version:  
major: 03  
minor: 03  
length: 0028  
fragment: 38807B6E5E0C3F4F7E0DBF7758031BF0  
7F100C4B63ADBC75F49BCBF428572D37

7CAED097336DB203

00000: 17 03 03 00 28 38 80 7B 6E 5E 0C 3F 4F 7E 0D BF  
00010: 77 58 03 1B F0 7F 10 0C 4B 63 AD BC 75 F4 9B CB  
00020: F4 28 57 2D 37 7C AE D0 97 33 6D B2 03

-----Server-----

Application data:

00000: FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF  
00010: FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF

Record layer message:

type: 17  
version:  
  major: 03  
  minor: 03  
length: 0028  
fragment: 05B869E5C979C3B9D4837B8E39D9BBEE  
1BBD0052D3D48340D0CDE082B33BC07F  
4E742D1113249AD8

00000: 17 03 03 00 28 05 B8 69 E5 C9 79 C3 B9 D4 83 7B  
00010: 8E 39 D9 BB EE 1B BD 00 52 D3 D4 83 40 D0 CD E0  
00020: 82 B3 3B C0 7F 4E 74 2D 11 13 24 9A D8

-----Client-----

close\_notify alert:

Alert:  
  level: 01  
  description: 00

00000: 01 00

Record layer message:

type: 15  
version:  
  major: 03  
  minor: 03  
length: 000A  
fragment: 4F2A0807A0374E28C632

00000: 15 03 03 00 0A 4F 2A 08 07 A0 37 4E 28 C6 32

-----Server-----

close\_notify alert:

Alert:  
  level: 01  
  description: 00

00000: 01 00



Record layer message:  
type: 15  
version:  
  major: 03  
  minor: 03  
length: 000A  
fragment: 999468B49AC5B0DE512C

00000: 15 03 03 00 0A 99 94 68 B4 9A C5 B0 DE 51 2C

#### A.1.3.2. TLS\_GOSTR341112\_256\_WITH\_KUZNYECHIK\_CTR\_OMAC Cipher Suite

Server certificate curve OID:  
id-tc26-gost-3410-2012-512-paramSetC, "1.2.643.7.1.2.1.2.3"

Server public key Q\_s:  
x = 0xF14589DA479AD972C66563669B3FF580  
  92E6A30A288BF447CD9FF6C3133E9724  
  7A9706B267703C9B4E239F0D7C7E3310  
  C22D2752B35BD2E4FD39B8F11DEB833A

y = 0xF305E95B36502D4E60A1059FB20AB30B  
  FC7C95727F3A2C04B1DFDDB53B0413F2  
  99F2DFE66A5E1CCB4101A7A01D612BE6  
  BD78E1E3B3D567EBB16ABE587A11F4EA

Server private key d\_s:  
0x12FD7A70067479A0F66C59F9A25534AD  
  FBC7ABFD3CC72D79806F8B402601644B  
  3005ED365A2D8989A8CCAE640D5FC08D  
  D27DFBBFE137CF528E1AC6D445192E01

Client certificate curve OID:  
id-tc26-gost-3410-2012-256-paramSetA, "1.2.643.7.1.2.1.1.1"

Client public key Q\_c:  
x = 0x0F5DB18A9E15F324B778676025BFD7B5  
  DF066566EABAA1C51CD879F87B0B4975

y = 0x9EE5BBF18361F842D3F087DEC2943939  
  E0FA2BFB4EDEC25A8D10ABB22C48F386

Client private key d\_c:  
0x0918AD3F7D209ABF89F1E8505DA894CE  
  E10DA09D32E72E815D9C0ADA30B5A103

-----Client-----

ClientHello message:  
msg\_type: 01  
length: 000040  
body:  
  client\_version:  
    major: 03

```

minor: 03
random: 933EA21EC3802A561550EC78D6ED51AC
 2439D7E749C31BC3A3456165889684CA

session_id:
 length: 00
 vector: --
cipher_suites:
 length: 0004
 vector:
 CipherSuite: C100
 CipherSuite: C101
compression_methods:
 length: 01
 vector:
 CompressionMethod: 00
extensions:
 length: 0013
 vector:
 Extension: /* signature_algorithms */
 extension_type: 000D
 extension_data:
 length: 0006
 vector:
 supported_signature_algorithms:
 length: 0004
 vector:
 /* 1 pair of algorithms */
 hash: 08
 signature: 40
 /* 2 pair of algorithms */
 hash: 08
 signature: 41
 Extension: /* renegotiation_info */
 extension_type: FF01
 extension_data:
 length: 0001
 vector:
 renegotiated_connection:
 length: 00
 vector: --
 Extension: /* extended_main_secret */
 extension_type: 0017
 extension_data:
 length: 0000
 vector: --

```

```

00000: 01 00 00 40 03 03 93 3E A2 1E C3 80 2A 56 15 50
00010: EC 78 D6 ED 51 AC 24 39 D7 E7 49 C3 1B C3 A3 45
00020: 61 65 88 96 84 CA 00 00 04 C1 00 C1 01 01 00 00
00030: 13 00 0D 00 06 00 04 08 40 08 41 FF 01 00 01 00
00040: 00 17 00 00

```

```

Record layer message:
type: 16

```

```

version:
 major: 03
 minor: 03
length: 0044
fragment: 010000400303933EA21EC3802A561550
 EC78D6ED51AC2439D7E749C31BC3A345
 6165889684CA000004C100C101010000
 13000D0006000408400841FF01000100
 00170000

```

```

00000: 16 03 03 00 44 01 00 00 40 03 03 93 3E A2 1E C3
00010: 80 2A 56 15 50 EC 78 D6 ED 51 AC 24 39 D7 E7 49
00020: C3 1B C3 A3 45 61 65 88 96 84 CA 00 00 04 C1 00
00030: C1 01 01 00 00 13 00 0D 00 06 00 04 08 40 08 41
00040: FF 01 00 01 00 00 17 00 00

```

-----Server-----

ServerHello message:

```

msg_type: 02
length: 000041
body:
 server_version:
 major: 03
 minor: 03
 random: 933EA21E49C31BC3A3456165889684CA
 A5576CE7924A24F58113808DBD9EF856

 session_id:
 length: 10
 vector: C3802A561550EC78D6ED51AC2439D7E7
 cipher_suite:
 CipherSuite: C100
 compression_method:
 CompressionMethod: 00
 extensions:
 length: 0009
 vector:
 Extension: /* renegotiation_info */
 extension_type: FF01
 extension_data:
 length: 0001
 vector:
 renegotiated_connection:
 length: 00
 vector: --
 Extension: /* extended_main_secret */
 extension_type: 0017
 extension_data:
 length: 0000
 vector: --

```

```

00000: 02 00 00 41 03 03 93 3E A2 1E 49 C3 1B C3 A3 45
00010: 61 65 88 96 84 CA A5 57 6C E7 92 4A 24 F5 81 13
00020: 80 8D BD 9E F8 56 10 C3 80 2A 56 15 50 EC 78 D6
00030: ED 51 AC 24 39 D7 E7 C1 00 00 00 09 FF 01 00 01

```

00040: 00 00 17 00 00

Record layer message:

type: 16

version:

major: 03

minor: 03

length: 0045

fragment: 020000410303933EA21E49C31BC3A345  
6165889684CAA5576CE7924A24F58113  
808DBD9EF85610C3802A561550EC78D6  
ED51AC2439D7E7C100000009FF010001  
0000170000

00000: 16 03 03 00 45 02 00 00 41 03 03 93 3E A2 1E 49

00010: C3 1B C3 A3 45 61 65 88 96 84 CA A5 57 6C E7 92

00020: 4A 24 F5 81 13 80 8D BD 9E F8 56 10 C3 80 2A 56

00030: 15 50 EC 78 D6 ED 51 AC 24 39 D7 E7 C1 00 00 00

00040: 09 FF 01 00 01 00 00 17 00 00

-----Server-----

Certificate message:

msg\_type: 0B

length: 00024C

body:

certificate\_list:

length: 000249

vector:

ASN.1Cert:

length: 000246

vector: 30820242308201AEA003020102020101

300A06082A850307010103033042312C

302A06092A864886F70D010901161D7A

371AF83C5BC58B366DFEFA7345D50317

867C177AC84AC07EE8612164629AB7BD

C48AA0F64A741FE7298E82C5BFCE8672

029F875391F7

00000: 0B 00 02 4C 00 02 49 00 02 46 30 82 02 42 30 82

00010: 01 AE A0 03 02 01 02 02 01 01 30 0A 06 08 2A 85

00020: 03 07 01 01 03 03 30 42 31 2C 30 2A 06 09 2A 86

00030: 48 86 F7 0D 01 09 01 16 1D 74 6C 73 31 32 5F 73

00040: 65 72 76 65 72 35 31 32 43 40 63 72 79 70 74 6F

00050: 70 72 6F 2E 72 75 31 12 30 10 06 03 55 04 03 13

00060: 09 53 65 72 76 65 72 35 31 32 30 1E 17 0D 31 37

00070: 30 35 32 35 30 39 32 35 31 38 5A 17 0D 33 30 30

00080: 35 30 31 30 39 32 35 31 38 5A 30 42 31 2C 30 2A

00090: 06 09 2A 86 48 86 F7 0D 01 09 01 16 1D 74 6C 73

000A0: 31 32 5F 73 65 72 76 65 72 35 31 32 43 40 63 72

000B0: 79 70 74 6F 70 72 6F 2E 72 75 31 12 30 10 06 03

000C0: 55 04 03 13 09 53 65 72 76 65 72 35 31 32 30 81

000D0: AA 30 21 06 08 2A 85 03 07 01 01 01 02 30 15 06

000E0: 09 2A 85 03 07 01 02 01 02 03 06 08 2A 85 03 07

```

000F0: 01 01 02 03 03 81 84 00 04 81 80 3A 83 EB 1D F1
00100: B8 39 FD E4 D2 5B B3 52 27 2D C2 10 33 7E 7C 0D
00110: 9F 23 4E 9B 3C 70 67 B2 06 97 7A 24 97 3E 13 C3
00120: F6 9F CD 47 F4 8B 28 0A A3 E6 92 80 F5 3F 9B 66
00130: 63 65 C6 72 D9 9A 47 DA 89 45 F1 EA F4 11 7A 58
00140: BE 6A B1 EB 67 D5 B3 E3 E1 78 BD E6 2B 61 1D A0
00150: A7 01 41 CB 1C 5E 6A E6 DF F2 99 F2 13 04 3B B5
00160: DD DF B1 04 2C 3A 7F 72 95 7C FC 0B B3 0A B2 9F
00170: 05 A1 60 4E 2D 50 36 5B E9 05 F3 A3 43 30 41 30
00180: 1D 06 03 55 1D 0E 04 16 04 14 87 9C C6 5A 0F 4A
00190: 89 CB 4A 58 49 DF 05 61 56 9B AA DC 11 69 30 0B
001A0: 06 03 55 1D 0F 04 04 03 02 03 28 30 13 06 03 55
001B0: 1D 25 04 0C 30 0A 06 08 2B 06 01 05 05 07 03 01
001C0: 30 0A 06 08 2A 85 03 07 01 01 03 03 03 81 81 00
001D0: 35 BE 38 51 EC B6 E9 2D 32 40 01 81 0F 8C 89 03
001E0: 52 42 F4 05 46 9F 4C 4E CB 05 02 7C 57 E2 71 52
001F0: 12 AF D7 CD BB 0C ED 7A 8B 4D 33 42 CC 50 1A BD
00200: 99 99 75 A5 8A DE 0E 58 4F CA 35 F5 2E 45 58 B7
00210: 31 1D 49 D0 A0 51 32 79 F7 39 37 1A F8 3C 5B C5
00220: 8B 36 6D FE FA 73 45 D5 03 17 86 7C 17 7A C8 4A
00230: C0 7E E8 61 21 64 62 9A B7 BD C4 8A A0 F6 4A 74
00240: 1F E7 29 8E 82 C5 BF CE 86 72 02 9F 87 53 91 F7

```

Record layer message:

```

type: 16
version:
 major: 03
 minor: 03
length: 0250
fragment: 0B00024C000249000246308202423082
01AEA003020102020101300A06082A85
0307010103033042312C302A06092A86

8B366DFEFA7345D50317867C177AC84A
C07EE8612164629AB7BDC48AA0F64A74
1FE7298E82C5BFCE8672029F875391F7

```

```

00000: 16 03 03 02 50 0B 00 02 4C 00 02 49 00 02 46 30
00010: 82 02 42 30 82 01 AE A0 03 02 01 02 02 01 01 30
00020: 0A 06 08 2A 85 03 07 01 01 03 03 30 42 31 2C 30
00030: 2A 06 09 2A 86 48 86 F7 0D 01 09 01 16 1D 74 6C
00040: 73 31 32 5F 73 65 72 76 65 72 35 31 32 43 40 63
00050: 72 79 70 74 6F 70 72 6F 2E 72 75 31 12 30 10 06
00060: 03 55 04 03 13 09 53 65 72 76 65 72 35 31 32 30
00070: 1E 17 0D 31 37 30 35 32 35 30 39 32 35 31 38 5A
00080: 17 0D 33 30 30 35 30 31 30 39 32 35 31 38 5A 30
00090: 42 31 2C 30 2A 06 09 2A 86 48 86 F7 0D 01 09 01
000A0: 16 1D 74 6C 73 31 32 5F 73 65 72 76 65 72 35 31
000B0: 32 43 40 63 72 79 70 74 6F 70 72 6F 2E 72 75 31
000C0: 12 30 10 06 03 55 04 03 13 09 53 65 72 76 65 72
000D0: 35 31 32 30 81 AA 30 21 06 08 2A 85 03 07 01 01
000E0: 01 02 30 15 06 09 2A 85 03 07 01 02 01 02 03 06
000F0: 08 2A 85 03 07 01 01 02 03 03 81 84 00 04 81 80
00100: 3A 83 EB 1D F1 B8 39 FD E4 D2 5B B3 52 27 2D C2
00110: 10 33 7E 7C 0D 9F 23 4E 9B 3C 70 67 B2 06 97 7A
00120: 24 97 3E 13 C3 F6 9F CD 47 F4 8B 28 0A A3 E6 92

```

```

00130: 80 F5 3F 9B 66 63 65 C6 72 D9 9A 47 DA 89 45 F1
00140: EA F4 11 7A 58 BE 6A B1 EB 67 D5 B3 E3 E1 78 BD
00150: E6 2B 61 1D A0 A7 01 41 CB 1C 5E 6A E6 DF F2 99
00160: F2 13 04 3B B5 DD DF B1 04 2C 3A 7F 72 95 7C FC
00170: 0B B3 0A B2 9F 05 A1 60 4E 2D 50 36 5B E9 05 F3
00180: A3 43 30 41 30 1D 06 03 55 1D 0E 04 16 04 14 87
00190: 9C C6 5A 0F 4A 89 CB 4A 58 49 DF 05 61 56 9B AA
001A0: DC 11 69 30 0B 06 03 55 1D 0F 04 04 03 02 03 28
001B0: 30 13 06 03 55 1D 25 04 0C 30 0A 06 08 2B 06 01
001C0: 05 05 07 03 01 30 0A 06 08 2A 85 03 07 01 01 03
001D0: 03 03 81 81 00 35 BE 38 51 EC B6 E9 2D 32 40 01
001E0: 81 0F 8C 89 03 52 42 F4 05 46 9F 4C 4E CB 05 02
001F0: 7C 57 E2 71 52 12 AF D7 CD BB 0C ED 7A 8B 4D 33
00200: 42 CC 50 1A BD 99 99 75 A5 8A DE 0E 58 4F CA 35
00210: F5 2E 45 58 B7 31 1D 49 D0 A0 51 32 79 F7 39 37
00220: 1A F8 3C 5B C5 8B 36 6D FE FA 73 45 D5 03 17 86
00230: 7C 17 7A C8 4A C0 7E E8 61 21 64 62 9A B7 BD C4
00240: 8A A0 F6 4A 74 1F E7 29 8E 82 C5 BF CE 86 72 02
00250: 9F 87 53 91 F7

```

-----Server-----

CertificateRequest message:

```

msg_type: 0D
length: 00000B
body:
 certificate_types:
 length: 02
 vector:
 /* gost_sign256 */
 43
 /* gost_sign512 */
 44
 supported_signature_algorithms:
 length: 0004
 vector:
 /* 1 pair of algorithms */
 hash: 08
 signature: 40
 /* 2 pair of algorithms */
 hash: 08
 signature: 41
 certificate_authorities:
 length: 0000
 vector: --

```

```

00000: 0D 00 00 0B 02 43 44 00 04 08 40 08 41 00 00

```

Record layer message:

```

type: 16
version:
 major: 03
 minor: 03
length: 000F
fragment: 0D00000B0243440004084008410000

```

00000: 16 03 03 00 0F 0D 00 00 0B 02 43 44 00 04 08 40  
00010: 08 41 00 00

-----Server-----

ServerHelloDone message:

msg\_type: 0E  
length: 000000  
body: --

00000: 0E 00 00 00

Record layer message:

type: 16  
version:  
  major: 03  
  minor: 03  
length: 0004  
fragment: 0E000000

00000: 16 03 03 00 04 0E 00 00 00

-----Client-----

Certificate message:

msg\_type: 0B  
length: 0001EA  
body:  
  certificate\_list:  
    length: 0001E7  
    vector:  
      ASN.1Cert:  
        length: 0001E4  
        vector: 308201E03082018DA003020102020101  
                 300A06082A850307010103023053312E  
                 302C06092A864886F70D010901161F74  
  
                 C1CAB43AC01AFB0F3451BDC2DB188BBC  
                 B77884251CDF6037BA830F4B31D5E96F  
                 DC9BC1C95ABE658266C48402E070DE1F  
                 292724E8

00000: 0B 00 01 EA 00 01 E7 00 01 E4 30 82 01 E0 30 82  
00010: 01 8D A0 03 02 01 02 02 01 01 30 0A 06 08 2A 85  
00020: 03 07 01 01 03 02 30 53 31 2E 30 2C 06 09 2A 86  
00030: 48 86 F7 0D 01 09 01 16 1F 74 6C 73 31 32 5F 63  
00040: 6C 69 65 6E 74 32 35 36 41 5F 45 40 63 72 79 70  
00050: 74 6F 70 72 6F 2E 72 75 31 21 30 1F 06 03 55 04  
00060: 03 1E 18 00 43 00 6C 00 69 00 65 00 6E 00 74 00  
00070: 32 00 35 00 36 00 41 00 5F 00 45 30 1E 17 0D 31  
00080: 37 30 35 32 35 30 39 33 31 31 38 5A 17 0D 33 30  
00090: 30 35 30 31 30 39 33 31 31 38 5A 30 53 31 2E 30  
000A0: 2C 06 09 2A 86 48 86 F7 0D 01 09 01 16 1F 74 6C

```

000B0: 73 31 32 5F 63 6C 69 65 6E 74 32 35 36 41 5F 45
000C0: 40 63 72 79 70 74 6F 70 72 6F 2E 72 75 31 21 30
000D0: 1F 06 03 55 04 03 1E 18 00 43 00 6C 00 69 00 65
000E0: 00 6E 00 74 00 32 00 35 00 36 00 41 00 5F 00 45
000F0: 30 68 30 21 06 08 2A 85 03 07 01 01 01 01 30 15
00100: 06 09 2A 85 03 07 01 02 01 01 01 06 08 2A 85 03
00110: 07 01 01 02 02 03 43 00 04 40 75 49 0B 7B F8 79
00120: D8 1C C5 A1 BA EA 66 65 06 DF B5 D7 BF 25 60 67
00130: 78 B7 24 F3 15 9E 8A B1 5D 0F 86 F3 48 2C B2 AB
00140: 10 8D 5A C2 DE 4E FB 2B FA E0 39 39 94 C2 DE 87
00150: F0 D3 42 F8 61 83 F1 BB E5 9E A3 43 30 41 30 1D
00160: 06 03 55 1D 0E 04 16 04 14 74 49 1E 77 30 D3 42
00170: A6 28 0E 72 A1 13 9D D9 90 8B FA F1 03 30 0B 06
00180: 03 55 1D 0F 04 04 03 02 07 80 30 13 06 03 55 1D
00190: 25 04 0C 30 0A 06 08 2B 06 01 05 05 07 03 02 30
001A0: 0A 06 08 2A 85 03 07 01 01 03 02 03 41 00 1C 2D
001B0: 35 22 B4 11 02 D6 20 1F 23 50 C1 CA B4 3A C0 1A
001C0: FB 0F 34 51 BD C2 DB 18 8B BC B7 78 84 25 1C DF
001D0: 60 37 BA 83 0F 4B 31 D5 E9 6F DC 9B C1 C9 5A BE
001E0: 65 82 66 C4 84 02 E0 70 DE 1F 29 27 24 E8

```

Record layer message:

```

type: 16
version:
 major: 03
 minor: 03
length: 01EE
fragment: 0B0001EA0001E70001E4308201E03082
018DA003020102020101300A06082A85
0307010103023053312E302C06092A86

3522B41102D6201F2350C1CAB43AC01A
FB0F3451BDC2DB188BBCB77884251CDF
6037BA830F4B31D5E96FDC9BC1C95ABE
658266C48402E070DE1F292724E8

```

```

00000: 16 03 03 01 EE 0B 00 01 EA 00 01 E7 00 01 E4 30
00010: 82 01 E0 30 82 01 8D A0 03 02 01 02 02 01 01 30
00020: 0A 06 08 2A 85 03 07 01 01 03 02 30 53 31 2E 30
00030: 2C 06 09 2A 86 48 86 F7 0D 01 09 01 16 1F 74 6C
00040: 73 31 32 5F 63 6C 69 65 6E 74 32 35 36 41 5F 45
00050: 40 63 72 79 70 74 6F 70 72 6F 2E 72 75 31 21 30
00060: 1F 06 03 55 04 03 1E 18 00 43 00 6C 00 69 00 65
00070: 00 6E 00 74 00 32 00 35 00 36 00 41 00 5F 00 45
00080: 30 1E 17 0D 31 37 30 35 32 35 30 39 33 31 31 38
00090: 5A 17 0D 33 30 30 35 30 31 30 39 33 31 31 38 5A
000A0: 30 53 31 2E 30 2C 06 09 2A 86 48 86 F7 0D 01 09
000B0: 01 16 1F 74 6C 73 31 32 5F 63 6C 69 65 6E 74 32
000C0: 35 36 41 5F 45 40 63 72 79 70 74 6F 70 72 6F 2E
000D0: 72 75 31 21 30 1F 06 03 55 04 03 1E 18 00 43 00
000E0: 6C 00 69 00 65 00 6E 00 74 00 32 00 35 00 36 00
000F0: 41 00 5F 00 45 30 68 30 21 06 08 2A 85 03 07 01
00100: 01 01 01 30 15 06 09 2A 85 03 07 01 02 01 01 01
00110: 06 08 2A 85 03 07 01 01 02 02 03 43 00 04 40 75
00120: 49 0B 7B F8 79 D8 1C C5 A1 BA EA 66 65 06 DF B5
00130: D7 BF 25 60 67 78 B7 24 F3 15 9E 8A B1 5D 0F 86

```



00140: F3 48 2C B2 AB 10 8D 5A C2 DE 4E FB 2B FA E0 39  
00150: 39 94 C2 DE 87 F0 D3 42 F8 61 83 F1 BB E5 9E A3  
00160: 43 30 41 30 1D 06 03 55 1D 0E 04 16 04 14 74 49  
00170: 1E 77 30 D3 42 A6 28 0E 72 A1 13 9D D9 90 8B FA  
00180: F1 03 30 0B 06 03 55 1D 0F 04 04 03 02 07 80 30  
00190: 13 06 03 55 1D 25 04 0C 30 0A 06 08 2B 06 01 05  
001A0: 05 07 03 02 30 0A 06 08 2A 85 03 07 01 01 03 02  
001B0: 03 41 00 1C 2D 35 22 B4 11 02 D6 20 1F 23 50 C1  
001C0: CA B4 3A C0 1A FB 0F 34 51 BD C2 DB 18 8B BC B7  
001D0: 78 84 25 1C DF 60 37 BA 83 0F 4B 31 D5 E9 6F DC  
001E0: 9B C1 C9 5A BE 65 82 66 C4 84 02 E0 70 DE 1F 29  
001F0: 27 24 E8

-----Client-----

PMS value:

00000: A5 57 6C E7 92 4A 24 F5 81 13 80 8D BD 9E F8 56  
00010: F5 BD C3 B1 83 CE 5D AD CA 36 A5 3A A0 77 65 1D

Random d\_eph value:

0x150ACD11B66DD695AD18418FA7A2DC63  
6B7E29DCA24536AABC826EE3175BB1FA  
DC3AA0D01D3092E120B0FCF7EB872F4B  
7E26EA17849D689222A48CF95A6E4831

Q\_eph ephemeral key:

x = 0xC941BE5193189B476D5A0334114A3E04  
BBE5B37C738AE40F150B334135288664  
FEBFC5622818894A07B1F7AD60E28480  
B4B637B90EA7D4BA980186B605D75BC6

y = 0xA154F7B93E8148652011F4FD52C9A06A  
6471ADB28D0A949AE26BC786DE874153  
ABC00B35164F3214A8A83C00ECE27831  
B093528456234EFE766224FC2A7E9ABE

HASH (r\_c | r\_s):

00000: C3 EF 04 28 D4 B7 A1 F4 C5 02 5F 2E 65 DD 2B 2E  
00010: A5 83 AE EF DB 67 C7 F4 21 4A 6A 29 8E 99 E3 25

Export key generation. r value:

0xC3EF0428D4B7A1F4C5025F2E65DD2B2E

Export key generation. UKM value:

0xC3EF0428D4B7A1F4C5025F2E65DD2B2E

Export keys K\_Exp\_MAC | K\_Exp\_ENC used in KExp15 algorithm:

00000: 7D AC 56 E4 8A 4D C1 70 FA A8 FC BA E2 0D B8 45  
00010: 45 0C CC C4 C6 32 8B DC 8D 01 15 7C EF A2 A5 F1  
00020: 1F 1C BA D8 86 61 66 F0 1F FA AB 01 52 E2 4B F4  
00030: 60 9D 5F 46 A5 C8 99 C7 87 90 0D 08 B9 FC AD 24

IV:

00000: 21 4A 6A 29 8E 99 E3 25

PMSEXP:

00000: 25 0D 1B 67 A2 70 AB 04 D3 F6 54 18 E1 D3 80 B4  
00010: CB 94 5F 0A 3D CA 51 50 0C F3 A1 BE F3 7F 76 C0  
00020: 73 41 A9 83 9C CF 6C BA 71 89 DA 61 EB 67 17 6C

-----Client-----

ClientKeyExchange message:

msg\_type: 10

length: 0000E2

body:

exchange\_keys: 3081DF0430250D1B67A270AB04D3F654  
18E1D380B4CB945F0A3DCA51500CF3A1  
BEF37F76C07341A9839CCF6CBA7189DA

93B03178E2EC003CA8A814324F16350B  
C0AB534187DE86C76BE29A940A8DB2AD  
71646AA0C952FDF411206548813EB9F7  
54A1

00000: 10 00 00 E2 30 81 DF 04 30 25 0D 1B 67 A2 70 AB  
00010: 04 D3 F6 54 18 E1 D3 80 B4 CB 94 5F 0A 3D CA 51  
00020: 50 0C F3 A1 BE F3 7F 76 C0 73 41 A9 83 9C CF 6C  
00030: BA 71 89 DA 61 EB 67 17 6C 30 81 AA 30 21 06 08  
00040: 2A 85 03 07 01 01 01 02 30 15 06 09 2A 85 03 07  
00050: 01 02 01 02 03 06 08 2A 85 03 07 01 01 02 03 03  
00060: 81 84 00 04 81 80 C6 5B D7 05 B6 86 01 98 BA D4  
00070: A7 0E B9 37 B6 B4 80 84 E2 60 AD F7 B1 07 4A 89  
00080: 18 28 62 C5 BF FE 64 86 28 35 41 33 0B 15 0F E4  
00090: 8A 73 7C B3 E5 BB 04 3E 4A 11 34 03 5A 6D 47 9B  
000A0: 18 93 51 BE 41 C9 BE 9A 7E 2A FC 24 62 76 FE 4E  
000B0: 23 56 84 52 93 B0 31 78 E2 EC 00 3C A8 A8 14 32  
000C0: 4F 16 35 0B C0 AB 53 41 87 DE 86 C7 6B E2 9A 94  
000D0: 0A 8D B2 AD 71 64 6A A0 C9 52 FD F4 11 20 65 48  
000E0: 81 3E B9 F7 54 A1

Record layer message:

type: 16

version:

major: 03

minor: 03

length: 00E6

fragment: 100000E23081DF0430250D1B67A270AB  
04D3F65418E1D380B4CB945F0A3DCA51  
500CF3A1BEF37F76C07341A9839CCF6C

2356845293B03178E2EC003CA8A81432  
4F16350BC0AB534187DE86C76BE29A94  
0A8DB2AD71646AA0C952FDF411206548  
813EB9F754A1

00000: 16 03 03 00 E6 10 00 00 E2 30 81 DF 04 30 25 0D  
00010: 1B 67 A2 70 AB 04 D3 F6 54 18 E1 D3 80 B4 CB 94  
00020: 5F 0A 3D CA 51 50 0C F3 A1 BE F3 7F 76 C0 73 41

00030: A9 83 9C CF 6C BA 71 89 DA 61 EB 67 17 6C 30 81  
00040: AA 30 21 06 08 2A 85 03 07 01 01 01 02 30 15 06  
00050: 09 2A 85 03 07 01 02 01 02 03 06 08 2A 85 03 07  
00060: 01 01 02 03 03 81 84 00 04 81 80 C6 5B D7 05 B6  
00070: 86 01 98 BA D4 A7 0E B9 37 B6 B4 80 84 E2 60 AD  
00080: F7 B1 07 4A 89 18 28 62 C5 BF FE 64 86 28 35 41  
00090: 33 0B 15 0F E4 8A 73 7C B3 E5 BB 04 3E 4A 11 34  
000A0: 03 5A 6D 47 9B 18 93 51 BE 41 C9 BE 9A 7E 2A FC  
000B0: 24 62 76 FE 4E 23 56 84 52 93 B0 31 78 E2 EC 00  
000C0: 3C A8 A8 14 32 4F 16 35 0B C0 AB 53 41 87 DE 86  
000D0: C7 6B E2 9A 94 0A 8D B2 AD 71 64 6A A0 C9 52 FD  
000E0: F4 11 20 65 48 81 3E B9 F7 54 A1

-----Server-----

PMSEXP extracted:

00000: 25 0D 1B 67 A2 70 AB 04 D3 F6 54 18 E1 D3 80 B4  
00010: CB 94 5F 0A 3D CA 51 50 0C F3 A1 BE F3 7F 76 C0  
00020: 73 41 A9 83 9C CF 6C BA 71 89 DA 61 EB 67 17 6C

HASH(r\_c | r\_s):

00000: C3 EF 04 28 D4 B7 A1 F4 C5 02 5F 2E 65 DD 2B 2E  
00010: A5 83 AE EF DB 67 C7 F4 21 4A 6A 29 8E 99 E3 25

Export key generation. r value:

0xC3EF0428D4B7A1F4C5025F2E65DD2B2E

Export key generation. UKM value:

0xC3EF0428D4B7A1F4C5025F2E65DD2B2E

Export keys K\_Exp\_MAC | K\_Exp\_ENC used in KImp15 algorithm:

00000: 7D AC 56 E4 8A 4D C1 70 FA A8 FC BA E2 0D B8 45  
00010: 45 0C CC C4 C6 32 8B DC 8D 01 15 7C EF A2 A5 F1  
00020: 1F 1C BA D8 86 61 66 F0 1F FA AB 01 52 E2 4B F4  
00030: 60 9D 5F 46 A5 C8 99 C7 87 90 0D 08 B9 FC AD 24

IV:

00000: 21 4A 6A 29 8E 99 E3 25

PMS:

00000: A5 57 6C E7 92 4A 24 F5 81 13 80 8D BD 9E F8 56  
00010: F5 BD C3 B1 83 CE 5D AD CA 36 A5 3A A0 77 65 1D

-----Client-----

Random value k used in signature generation:

0x163962EEA268203E7C6B3F70BF8D4A36  
34CE6E2CFC424687951D70ACE0B4292A

Signature value sgn\_c = SIGN\_d\_c(HM):

00000: F7 1F 43 62 45 5B C5 5B A8 9A 8F AF 01 82 88 EC  
00010: 00 B3 27 17 48 2E 76 24 B2 57 D9 79 7C 8F F6 02  
00020: E3 15 FD BD 8D E5 6D 08 54 18 04 0E 1B 61 BB F6  
00030: B3 01 AC 26 3D 50 03 8B 30 31 13 DB 36 17 50 3A

-----Client-----

CertificateVerify message:

msg\_type: 0F  
length: 000044  
body:  
  algorithm:  
    hash: 08  
    signature: 40  
  signature:  
    length: 0040  
    vector: F71F4362455BC55BA89A8FAF018288EC  
            00B32717482E7624B257D9797C8FF602  
            E315FDBD8DE56D085418040E1B61BBF6  
            B301AC263D50038B303113DB3617503A

00000: 0F 00 00 44 08 40 00 40 F7 1F 43 62 45 5B C5 5B  
00010: A8 9A 8F AF 01 82 88 EC 00 B3 27 17 48 2E 76 24  
00020: B2 57 D9 79 7C 8F F6 02 E3 15 FD BD 8D E5 6D 08  
00030: 54 18 04 0E 1B 61 BB F6 B3 01 AC 26 3D 50 03 8B  
00040: 30 31 13 DB 36 17 50 3A

Record layer message:

type: 16  
version:  
  major: 03  
  minor: 03  
length: 0048  
fragment: 0F00004408400040F71F4362455BC55B  
          A89A8FAF018288EC00B32717482E7624  
          B257D9797C8FF602E315FDBD8DE56D08  
          5418040E1B61BBF6B301AC263D50038B  
          303113DB3617503A

00000: 16 03 03 00 48 0F 00 00 44 08 40 00 40 F7 1F 43  
00010: 62 45 5B C5 5B A8 9A 8F AF 01 82 88 EC 00 B3 27  
00020: 17 48 2E 76 24 B2 57 D9 79 7C 8F F6 02 E3 15 FD  
00030: BD 8D E5 6D 08 54 18 04 0E 1B 61 BB F6 B3 01 AC  
00040: 26 3D 50 03 8B 30 31 13 DB 36 17 50 3A

-----Client-----

HASH(HM):

00000: 9D 64 0D D8 B2 54 6B 87 05 CC 3E 67 F3 BB 83 2F  
00010: 89 2A 5B D5 D4 5C A0 44 85 01 14 C2 E6 56 02 69

MS:

00000: E3 18 17 B0 EC 7F 3B C9 4A 8B C4 5F 89 12 DE C5  
00010: 71 2A 7A 34 78 56 31 C0 4B AE 81 43 EE 17 90 B4  
00020: C9 D3 68 0F 6C 9D E1 70 74 58 C8 75 62 4D B6 ED

Client connection key material

K\_write\_MAC|K\_read\_MAC|K\_write\_ENC|K\_read\_ENC|IV\_write|IV\_read:

```
00000: 50 52 5D 33 4E F7 00 6C 1D ED B8 B8 08 EA 03 CC
00010: CF 1F CB 3D 33 65 F9 72 E1 7C 7C 31 4E DD 97 90
00020: 6C 74 35 22 0A A1 B0 C6 DE 6A 1B 0F AC 29 B6 17
00030: 9E B3 23 86 62 25 E0 7F 30 4C A1 D1 27 75 86 29
00040: 7B 97 20 5D 7A 08 C2 CD 7F 60 3C 09 46 75 E6 C4
00050: CC 15 F2 84 0D 9A EC 63 F0 2A FF 51 DB D5 74 D2
00060: 76 6C 77 2B 83 2F CE 58 CB 4D E5 49 88 77 A6 7A
00070: A4 51 40 B2 ED 52 6E 61 65 0A 28 1B 32 56 35 BC
00080: CB 8E F9 4C 5B DF 5B 9F 47 48 B9 5B F1 B0 E0 BF
```

-----Server-----

HASH(HM):

```
00000: 9D 64 0D D8 B2 54 6B 87 05 CC 3E 67 F3 BB 83 2F
00010: 89 2A 5B D5 D4 5C A0 44 85 01 14 C2 E6 56 02 69
```

MS:

```
00000: E3 18 17 B0 EC 7F 3B C9 4A 8B C4 5F 89 12 DE C5
00010: 71 2A 7A 34 78 56 31 C0 4B AE 81 43 EE 17 90 B4
00020: C9 D3 68 0F 6C 9D E1 70 74 58 C8 75 62 4D B6 ED
```

Server connection key material

K\_read\_MAC|K\_write\_MAC|K\_read\_ENC|K\_write\_ENC|IV\_read|IV\_write:

```
00000: 50 52 5D 33 4E F7 00 6C 1D ED B8 B8 08 EA 03 CC
00010: CF 1F CB 3D 33 65 F9 72 E1 7C 7C 31 4E DD 97 90
00020: 6C 74 35 22 0A A1 B0 C6 DE 6A 1B 0F AC 29 B6 17
00030: 9E B3 23 86 62 25 E0 7F 30 4C A1 D1 27 75 86 29
00040: 7B 97 20 5D 7A 08 C2 CD 7F 60 3C 09 46 75 E6 C4
00050: CC 15 F2 84 0D 9A EC 63 F0 2A FF 51 DB D5 74 D2
00060: 76 6C 77 2B 83 2F CE 58 CB 4D E5 49 88 77 A6 7A
00070: A4 51 40 B2 ED 52 6E 61 65 0A 28 1B 32 56 35 BC
00080: CB 8E F9 4C 5B DF 5B 9F 47 48 B9 5B F1 B0 E0 BF
```

-----Client-----

ChangeCipherSpec message:

type: 01

00000: 01

Record layer message:

type: 14

version:

major: 03

minor: 03

length: 0001

fragment: 01

00000: 14 03 03 00 01 01

-----Client-----

HASH(HM):

00000: C9 A4 80 DA 29 6C DD 12 3E 9A EB 26 88 8B 86 19  
00010: EA 67 78 B7 23 FA A8 B2 DC 70 6A CB A5 AB AF 11

client\_verify\_data:

00000: 98 7C 13 E6 FA 16 F3 D5 10 AE 83 00 23 58 72 27  
00010: 32 90 09 4C 8F C7 B5 F0 C7 D7 47 C4 27 35 F8 F1

-----Client-----

Finished message:

msg\_type: 14  
length: 000020  
body:  
verify\_data: 987C13E6FA16F3D510AE830023587227  
3290094C8FC7B5F0C7D747C42735F8F1

00000: 14 00 00 20 98 7C 13 E6 FA 16 F3 D5 10 AE 83 00  
00010: 23 58 72 27 32 90 09 4C 8F C7 B5 F0 C7 D7 47 C4  
00020: 27 35 F8 F1

Record layer message:

type: 16  
version:  
major: 03  
minor: 03  
length: 0034  
fragment: 4DC53D655EDFD1843AF69ADBDE989C0B  
1F0C0A1A0FD1B3F458029D8F9989F8F9  
6C5C42971063A9B70714F412E4F6280F  
7C21601B

00000: 16 03 03 00 34 4D C5 3D 65 5E DF D1 84 3A F6 9A  
00010: DB DE 98 9C 0B 1F 0C 0A 1A 0F D1 B3 F4 58 02 9D  
00020: 8F 99 89 FB F9 6C 5C 42 97 10 63 A9 B7 07 14 F4  
00030: 12 E4 F6 28 0F 7C 21 60 1B

-----Server-----

ChangeCipherSpec message:

type: 01

00000: 01

Record layer message:

type: 14  
version:  
major: 03  
minor: 03  
length: 0001  
fragment: 01

00000: 14 03 03 00 01 01

-----Server-----

HASH(HM):

00000: 4A 41 4C AD 20 F8 46 D8 F5 D1 05 26 10 A5 9D ED  
00010: 6D 2B 1B B2 A8 9E 13 51 01 FC 9E 49 ED A8 0F B4

server\_verify\_data:

00000: 1E 93 7D A4 77 EE 1F 23 0A 41 D6 E9 D4 14 46 B7  
00010: F2 1C A1 B2 E2 32 4A 55 2D 52 B3 25 5E B4 3D DF

-----Server-----

Finished message:

msg\_type: 14  
length: 000020  
body:  
verify\_data: 1E937DA477EE1F230A41D6E9D41446B7  
F21CA1B2E2324A552D52B3255EB43DDF

00000: 14 00 00 20 1E 93 7D A4 77 EE 1F 23 0A 41 D6 E9  
00010: D4 14 46 B7 F2 1C A1 B2 E2 32 4A 55 2D 52 B3 25  
00020: 5E B4 3D DF

Record layer message:

type: 16  
version:  
major: 03  
minor: 03  
length: 0034  
fragment: F9887C3654B6CCC6AE7D7B18A46C663F  
3D1DAF30C9A853A9871077FDD5CA063B  
2C81BCC9D59FA6E3F5FAD9B2599BB586  
854A2D76

00000: 16 03 03 00 34 F9 88 7C 36 54 B6 CC C6 AE 7D 7B  
00010: 18 A4 6C 66 3F 3D 1D AF 30 C9 A8 53 A9 87 10 77  
00020: FD D5 CA 06 3B 2C 81 BC C9 D5 9F A6 E3 F5 FA D9  
00030: B2 59 9B B5 86 85 4A 2D 76

-----Client-----

Application data:

00000: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  
00010: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00

Record layer message:

type: 17  
version:  
major: 03  
minor: 03  
length: 0030  
fragment: F14F06FB8557408846080690E7A5525D  
1C6E9C901D24025486AB79728BF63D06  
5C09C27233006D65CFF0B5BA87504969

```
00000: 17 03 03 00 30 F1 4F 06 FB 85 57 40 88 46 08 06
00010: 90 E7 A5 52 5D 1C 6E 9C 90 1D 24 02 54 86 AB 79
00020: 72 8B F6 3D 06 5C 09 C2 72 33 00 6D 65 CF F0 B5
00030: BA 87 50 49 69
```

-----Server-----

Application data:

```
00000: FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
00010: FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
```

Record layer message:

```
type: 17
version:
 major: 03
 minor: 03
length: 0030
fragment: 1561E52A8B6DB258746FFE18F3CDCB11
 1D0173AF2E5C13741C99BFF13B47CD32
 B3CED856A9506E706A2340D5841AB114
```

```
00000: 17 03 03 00 30 15 61 E5 2A 8B 6D B2 58 74 6F FE
00010: 18 F3 CD CB 11 1D 01 73 AF 2E 5C 13 74 1C 99 BF
00020: F1 3B 47 CD 32 B3 CE D8 56 A9 50 6E 70 6A 23 40
00030: D5 84 1A B1 14
```

-----Client-----

close\_notify alert:

```
Alert:
 level: 01
 description: 00
```

```
00000: 01 00
```

Record layer message:

```
type: 15
version:
 major: 03
 minor: 03
length: 0012
fragment: E530C164642A078CEF528CB465E9DA7E
 AD4D
```

```
00000: 15 03 03 00 12 E5 30 C1 64 64 2A 07 8C EF 52 8C
00010: B4 65 E9 DA 7E AD 4D
```

-----Server-----

close\_notify alert:

```
Alert:
 level: 01
```



```

description: 00

00000: 01 00

Record layer message:
type: 15
version:
 major: 03
 minor: 03
length: 0012
fragment: EB62E5AB78BF2A4B678920A11027EC43
 0C3F

00000: 15 03 03 00 12 EB 62 E5 AB 78 BF 2A 4B 67 89 20
00010: A1 10 27 EC 43 0C 3F

```

## A.2. Test Examples for CNT\_IMIT Cipher Suites

### A.2.1. Record Examples

It is assumed that the following keys were established during handshake:

```

- MAC key:
00000: ff ff ff ff ff ff ff ff ff ff ff ff ff ff ff ff
00010: ff ff ff ff ff ff ff ff ff ff ff ff ff ff ff ff
- Encryption key:
00000: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00010: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
- IV:
00000: 00 00 00 00 00 00 00 00

```

```

seqnum = 0

```

```

Application data:
00000: 00 00 00 00 00 00 00 00

```

```

Plaintext:
00000: 17 03 03 00 07 00 00 00 00 00 00 00 00 00

```

```

MAC:
00000: 30 01 34 a1

```

```

Ciphertext:
00000: 17 03 03 00 0b 86 71 cd bf 3c 1a ae 0f 62 4b 04

```

```

seqnum = 1

```

```

Application data:

00000: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00010: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
007f0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00

```

**Plaintext:**

```

00000: 17 03 03 08 00 00 00 00 00 00 00 00 00 00 00 00
00010: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
...
007f0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00804: 00 00 00 00 00

```

**MAC:**

```

00000: f7 c3 8b 8a

```

**Ciphertext:**

```

00000: 17 03 03 08 04 cf aa 0c b4 2f a5 a4 7a 13 3d 73
00010: b9 f2 c0 b0 4f 8c a2 55 52 f8 56 bc be 6a 58 fa
...
007f0: 3e e2 c7 6f a2 30 a0 44 be 21 dc 8e 1a 96 f9 a8
00804: 88 1f ad 83 45 96 96 84 47

```

**A.2.2. Handshake Examples**

The `ClientHello.extensions` and the `ServerHello.extensions` fields contain the `renegotiation_info` extension (see [RFC5746]) in the following examples.

**Server certificate curve OID:**

```

id-tc26-gost-3410-12-512-paramSetA, "1.2.643.7.1.2.1.2.1"

```

**Server public key Q\_s:**

```

x = 0x16DB0566C0278AC8204143994824236D
 97F36A13D5433E990B2EAC859D2E9B7A
 E054794655389158B8242923E3841B14
 24FD89F221701C89D9A3BF6A9F946795

```

```

y = 0xD01E80DEC5BD23C8BC6B85F12BBB1635
 A5AE7AD50DE24FB8FD02CB285A4AE65A
 7D6FBB99AAFFDA80629826F2F7F73282
 220444761615A06D082077C4A00FD4CF

```

**Server private key d\_s:**

```

0x5F1E83AFA2C4CB2C5633C51380E84E37
 4B013EE7C238330709080CE914B442D4
 34EB016D23FB63FEDC18B62D9DA93D26
 B3B9CE6F663B383303BD5930ED41608B

```

-----Client-----

**ClientHello message:**

```

msg_type: 01
length: 00003a
body:
 client_version:
 major: 03
 minor: 03
 random: 6A523D6880DCC2DC75CCC43CFD04B616
 F5C3757B8077B76A9B504949FD3BFDB8

```

```

session_id:
 length: 00
 vector: --
cipher_suites:
 length: 0002
 vector:
 CipherSuite: C102
compression_methods:
 length: 01
 vector:
 CompressionMethod: 00
extensions:
 length: 000F
 Extension: /* signature_algorithms */
 extension_type: 000D
 extension_data:
 length: 0006
 vector:
 supported_signature_algorithms:
 length: 0004
 vector:
 /* 1 pair of algorithms */
 hash: 08
 signature: 41
 /* 2 pair of algorithms */
 hash: 08
 signature: 40
 Extension: /* renegotiation_info */
 extension_type: FF01
 extension_data:
 length: 0001
 vector:
 renegotiated_connection:
 length: 00
 vector: --

```

```

00000: 01 00 00 3A 03 03 6A 52 3D 68 80 DC C2 DC 75 CC
00010: C4 3C FD 04 B6 16 F5 C3 75 7B 80 77 B7 6A 9B 50
00020: 49 49 FD 3B FD B8 00 00 02 C1 02 01 00 00 0F 00
00030: 0D 00 06 00 04 08 41 08 40 FF 01 00 01 00

```

Record layer message:

```

type: 16
version:
 major: 03
 minor: 03
length: 003e
fragment: 0100003A03036A523D6880DCC2DC75CC
 C43CFD04B616F5C3757B8077B76A9B50
 4949FD3BFDB8000002C1020100000F00
 0D0006000408410840FF01000100

```

```

00000: 16 03 03 00 3E 01 00 00 3A 03 03 6A 52 3D 68 80
00010: DC C2 DC 75 CC C4 3C FD 04 B6 16 F5 C3 75 7B 80

```

```
00020: 77 B7 6A 9B 50 49 49 FD 3B FD B8 00 00 02 C1 02
00030: 01 00 00 0F 00 0D 00 06 00 04 08 41 08 40 FF 01
00040: 00 01 00
```

-----Server-----

ServerHello message:

```
msg_type: 02
length: 00004D
body:
 client_version:
 major: 03
 minor: 03
 random: FE92C9516D0E1A67A04C33CD7F2C90B1
 5E76DCC30815C19F92A6D100915AF2DB
 session_id:
 length: 20
 vector: 12AAA5E5779014711CCD6D265BDEE519
 1026431C83768EE5EB5A157F940BE9FB
 cipher_suite:
 CipherSuite: C102
 compression_method:
 CompressionMethod: 00
 extensions:
 length: 0005
 Extension: /* renegotiation_info */
 extension_type: FF01
 extension_data:
 length: 0001
 vector:
 renegotiated_connection:
 length: 00
 vector: --
```

```
00000: 02 00 00 4D 03 03 FE 92 C9 51 6D 0E 1A 67 A0 4C
00010: 33 CD 7F 2C 90 B1 5E 76 DC C3 08 15 C1 9F 92 A6
00020: D1 00 91 5A F2 DB 20 12 AA A5 E5 77 90 14 71 1C
00030: CD 6D 26 5B DE E5 19 10 26 43 1C 83 76 8E E5 EB
00040: 5A 15 7F 94 0B E9 FB C1 02 00 00 05 FF 01 00 01
00050: 00
```

Record layer message:

```
type: 16
version:
 major: 03
 minor: 03
length: 0051
fragment: 0200004D0303FE92C9516D0E1A67A04C
 33CD7F2C90B15E76DCC30815C19F92A6
 D100915AF2DB2012AAA5E5779014711C
 CD6D265BDEE5191026431C83768EE5EB
 5A157F940BE9FBC102000005FF010001
 00
```

```
00000: 16 03 03 00 51 02 00 00 4D 03 03 FE 92 C9 51 6D
```

00010: 0E 1A 67 A0 4C 33 CD 7F 2C 90 B1 5E 76 DC C3 08  
00020: 15 C1 9F 92 A6 D1 00 91 5A F2 DB 20 12 AA A5 E5  
00030: 77 90 14 71 1C CD 6D 26 5B DE E5 19 10 26 43 1C  
00040: 83 76 8E E5 EB 5A 15 7F 94 0B E9 FB C1 02 00 00  
00050: 05 FF 01 00 01 00

-----Server-----

Certificate message:

msg\_type: 0B  
length: 000266

body:

certificate\_list:  
length: 000263

vector:

ASN.1Cert:

length: 000260

vector: 3082025C308201C8A003020102021478  
94DC9D920977809191642F1DAEDC26BA  
3B5104300A06082A8503070101030330

6C12D51F99C98A4A9904F0EA5486FED7  
FF66AB8EB2425E1ACEAE8A758BDF843B  
E1A8F6FEBF673015FED7AB86533DBF20

00000: 0B 00 02 66 00 02 63 00 02 60 30 82 02 5C 30 82  
00010: 01 C8 A0 03 02 01 02 02 14 78 94 DC 9D 92 09 77  
00020: 80 91 91 64 2F 1D AE DC 26 BA 3B 51 04 30 0A 06  
00030: 08 2A 85 03 07 01 01 03 03 30 19 31 17 30 15 06  
00040: 03 55 04 03 13 0E 43 41 20 43 65 72 74 69 66 69  
00050: 63 61 74 65 30 1E 17 0D 31 38 30 31 30 32 30 30  
00060: 30 30 31 31 5A 17 0D 32 32 30 31 30 32 30 30 30  
00070: 30 32 31 5A 30 21 31 1F 30 1D 06 03 55 04 03 13  
00080: 16 53 65 72 76 65 72 20 35 31 32 20 43 65 72 74  
00090: 69 66 69 63 61 74 65 30 81 AA 30 21 06 08 2A 85  
000a0: 03 07 01 01 01 02 30 15 06 09 2A 85 03 07 01 02  
000b0: 01 02 01 06 08 2A 85 03 07 01 01 02 03 03 81 84  
000c0: 00 04 81 80 95 67 94 9F 6A BF A3 D9 89 1C 70 21  
000d0: F2 89 FD 24 14 1B 84 E3 23 29 24 B8 58 91 38 55  
000e0: 46 79 54 E0 7A 9B 2E 9D 85 AC 2E 0B 99 3E 43 D5  
000f0: 13 6A F3 97 6D 23 24 48 99 43 41 20 C8 8A 27 C0  
00100: 66 05 DB 16 CF D4 0F A0 C4 77 20 08 6D A0 15 16  
00110: 76 44 04 22 82 32 F7 F7 F2 26 98 62 80 DA FF AA  
00120: 99 BB 6F 7D 5A E6 4A 5A 28 CB 02 FD B8 4F E2 0D  
00130: D5 7A AE A5 35 16 BB 2B F1 85 6B BC C8 23 BD C5  
00140: DE 80 1E D0 A3 81 93 30 81 90 30 0C 06 03 55 1D  
00150: 13 01 01 FF 04 02 30 00 30 1A 06 03 55 1D 11 04  
00160: 13 30 11 82 09 6C 6F 63 61 6C 68 6F 73 74 87 04  
00170: 7F 00 00 01 30 13 06 03 55 1D 25 04 0C 30 0A 06  
00180: 08 2B 06 01 05 05 07 03 01 30 0F 06 03 55 1D 0F  
00190: 01 01 FF 04 05 03 03 07 B0 00 30 1D 06 03 55 1D  
001a0: 0E 04 16 04 14 AE 46 41 1B FD B3 08 C3 39 03 47  
001b0: 57 57 2B 0F BF A3 6F 9A 99 30 1F 06 03 55 1D 23  
001c0: 04 18 30 16 80 14 7F 7B 7A 15 61 A6 F2 18 A2 E3  
001d0: 48 3B C6 39 D9 7F 42 DB 6D AF 30 0A 06 08 2A 85

001e0: 03 07 01 01 03 03 03 81 81 00 9C 49 78 F7 1B AB  
001f0: 54 8A 25 6D 2A 18 7C A8 4D 72 4F E1 EF A7 E5 36  
00200: 67 2E 79 1F 8A 0C B6 74 1E B1 63 E2 96 37 8C 5B  
00210: 82 83 EE DA B4 1B A4 22 1E BC E2 05 F6 F8 79 CF  
00220: EB F0 AD E9 36 07 0F B2 40 E5 0D 04 37 03 7F 2A  
00230: EC 99 C7 CD 23 9F 6F 20 25 A8 6C 12 D5 1F 99 C9  
00240: 8A 4A 99 04 F0 EA 54 86 FE D7 FF 66 AB 8E B2 42  
00250: 5E 1A CE AE 8A 75 8B DF 84 3B E1 A8 F6 FE BF 67  
00260: 30 15 FE D7 AB 86 53 3D BF 20

Record layer message:

type: 16  
version:  
  major: 03  
  minor: 03  
length: 026A  
fragment: 0B0002660002630002603082025C3082  
01C8A00302010202147894DC9D920977  
809191642F1DAEDC26BA3B5104300A06  
  
EC99C7CD239F6F2025A86C12D51F99C9  
8A4A9904F0EA5486FED7FF66AB8EB242  
5E1ACEAE8A758BDF843BE1A8F6FEBF67  
3015FED7AB86533DBF20

00000: 16 03 03 02 6A 0B 00 02 66 00 02 63 00 02 60 30  
00010: 82 02 5C 30 82 01 C8 A0 03 02 01 02 02 14 78 94  
00020: DC 9D 92 09 77 80 91 91 64 2F 1D AE DC 26 BA 3B  
00030: 51 04 30 0A 06 08 2A 85 03 07 01 01 03 03 30 19  
00040: 31 17 30 15 06 03 55 04 03 13 0E 43 41 20 43 65  
00050: 72 74 69 66 69 63 61 74 65 30 1E 17 0D 31 38 30  
00060: 31 30 32 30 30 30 30 31 31 5A 17 0D 32 32 30 31  
00070: 30 32 30 30 30 30 32 31 5A 30 21 31 1F 30 1D 06  
00080: 03 55 04 03 13 16 53 65 72 76 65 72 20 35 31 32  
00090: 20 43 65 72 74 69 66 69 63 61 74 65 30 81 AA 30  
000a0: 21 06 08 2A 85 03 07 01 01 01 02 30 15 06 09 2A  
000b0: 85 03 07 01 02 01 02 01 06 08 2A 85 03 07 01 01  
000c0: 02 03 03 81 84 00 04 81 80 95 67 94 9F 6A BF A3  
000d0: D9 89 1C 70 21 F2 89 FD 24 14 1B 84 E3 23 29 24  
000e0: B8 58 91 38 55 46 79 54 E0 7A 9B 2E 9D 85 AC 2E  
000f0: 0B 99 3E 43 D5 13 6A F3 97 6D 23 24 48 99 43 41  
00100: 20 C8 8A 27 C0 66 05 DB 16 CF D4 0F A0 C4 77 20  
00110: 08 6D A0 15 16 76 44 04 22 82 32 F7 F7 F2 26 98  
00120: 62 80 DA FF AA 99 BB 6F 7D 5A E6 4A 5A 28 CB 02  
00130: FD B8 4F E2 0D D5 7A AE A5 35 16 BB 2B F1 85 6B  
00140: BC C8 23 BD C5 DE 80 1E D0 A3 81 93 30 81 90 30  
00150: 0C 06 03 55 1D 13 01 01 FF 04 02 30 00 30 1A 06  
00160: 03 55 1D 11 04 13 30 11 82 09 6C 6F 63 61 6C 68  
00170: 6F 73 74 87 04 7F 00 00 01 30 13 06 03 55 1D 25  
00180: 04 0C 30 0A 06 08 2B 06 01 05 05 07 03 01 30 0F  
00190: 06 03 55 1D 0F 01 01 FF 04 05 03 03 07 B0 00 30  
001a0: 1D 06 03 55 1D 0E 04 16 04 14 AE 46 41 1B FD B3  
001b0: 08 C3 39 03 47 57 57 2B 0F BF A3 6F 9A 99 30 1F  
001c0: 06 03 55 1D 23 04 18 30 16 80 14 7F 7B 7A 15 61  
001d0: A6 F2 18 A2 E3 48 3B C6 39 D9 7F 42 DB 6D AF 30  
001e0: 0A 06 08 2A 85 03 07 01 01 03 03 03 81 81 00 9C

```
001f0: 49 78 F7 1B AB 54 8A 25 6D 2A 18 7C A8 4D 72 4F
00200: E1 EF A7 E5 36 67 2E 79 1F 8A 0C B6 74 1E B1 63
00210: E2 96 37 8C 5B 82 83 EE DA B4 1B A4 22 1E BC E2
00220: 05 F6 F8 79 CF EB F0 AD E9 36 07 0F B2 40 E5 0D
00230: 04 37 03 7F 2A EC 99 C7 CD 23 9F 6F 20 25 A8 6C
00240: 12 D5 1F 99 C9 8A 4A 99 04 F0 EA 54 86 FE D7 FF
00250: 66 AB 8E B2 42 5E 1A CE AE 8A 75 8B DF 84 3B E1
00260: A8 F6 FE BF 67 30 15 FE D7 AB 86 53 3D BF 20
```

-----Server-----

ServerHelloDone message:

```
msg_type: 0E
length: 000000
body: --
```

```
00000: 0E 00 00 00
```

Record layer message::

```
type: 16
version:
 major: 03
 minor: 03
length: 0004
fragment: 0E000000
```

```
00000: 16 03 03 00 04 0E 00 00 00
```

-----Client-----

PMS:

```
00000: CE 0D D6 B6 70 42 12 15 2B E4 69 5A 7E 89 F6 4C
00010: 89 29 A4 0D BF 0A 5A 55 C2 CE 00 2B 06 BA B6 2F
```

Random d\_eph value:

```
0xC96486B1A3732389A162F5AD0145D537
43C9AC27D42ACF1091CE7EF67E6C3CCA
0F6C879B2DA3C1607648BAEB96471BD2
078DF5CAAA4FA83ECC0FFD6D3C8E5D56
```

Q\_eph ephemeral key:

```
x = 0x4B9CB381BCC737E493E43B2D7FD95BFE
2AEF6BE8F6224882E5E559ADA08170DC
49A815B3A1B3B323D2B50195153CFC60
DD6139C3770C5762A6A7719FABF84BFB
```

```
y = 0x95CEF28392C846A5EEFCB51C84E4960A
77B77D0D85EBD22061BFDA0013C5AB6C
42DDD04973F65D2AEB8A5427A53D6872
CF2D68F5F722C4640D7AAF2E0194FBD0
```

HASH(r\_c | r\_s):

```
00000: FB F3 9D 10 E8 00 AF 70 E7 AA 22 C1 10 DA 94 A9
00010: 9A 58 98 D8 45 27 C7 CB DE C1 1E 53 39 90 6A 1A
```

K\_EXP:  
00000: 3F D9 99 D1 68 4A 15 CC 9B DD 5A 35 06 7A F6 98  
00010: 17 15 00 22 E0 95 54 AC 79 1A 60 F1 61 F5 53 49

IV:  
00000: FB F3 9D 10 E8 00 AF 70

CEK\_ENC:  
00000: D6 22 D1 67 A5 64 2E 29 52 5A 29 5C B9 F2 8F 96  
00010: F2 8B 0E FA A7 D3 A2 BE E1 49 B0 11 78 C2 DF D5

CEK\_MAC:  
00000: 4C 93 36 57

PMSEXP:  
00000: FB F3 9D 10 E8 00 AF 70 D6 22 D1 67 A5 64 2E 29  
00010: 52 5A 29 5C B9 F2 8F 96 F2 8B 0E FA A7 D3 A2 BE  
00020: E1 49 B0 11 78 C2 DF D5 4C 93 36 57

-----Client-----

ClientKeyExchange message:

msg\_type: 10  
length: 0000F5  
body:  
exchange\_keys: 3081F23081EF30280420D622D167A564  
2E29525A295CB9F28F96F28B0EFAA7D3  
A2BEE149B01178C2DFD504044C933657  
  
DABF6120D2EB850D7DB7770A96E4841C  
B5FCCEEA546C89283F2CE950408FBF39D  
10E800AF70

00000: 10 00 00 F5 30 81 F2 30 81 EF 30 28 04 20 D6 22  
00010: D1 67 A5 64 2E 29 52 5A 29 5C B9 F2 8F 96 F2 8B  
00020: 0E FA A7 D3 A2 BE E1 49 B0 11 78 C2 DF D5 04 04  
00030: 4C 93 36 57 A0 81 C2 06 09 2A 85 03 07 01 02 05  
00040: 01 01 A0 81 AA 30 21 06 08 2A 85 03 07 01 01 01  
00050: 02 30 15 06 09 2A 85 03 07 01 02 01 02 01 06 08  
00060: 2A 85 03 07 01 01 02 03 03 81 84 00 04 81 80 FB  
00070: 4B F8 AB 9F 71 A7 A6 62 57 0C 77 C3 39 61 DD 60  
00080: FC 3C 15 95 01 B5 D2 23 B3 B3 A1 B3 15 A8 49 DC  
00090: 70 81 A0 AD 59 E5 E5 82 48 22 F6 E8 6B EF 2A FE  
000A0: 5B D9 7F 2D 3B E4 93 E4 37 C7 BC 81 B3 9C 4B D0  
000B0: FB 94 01 2E AF 7A 0D 64 C4 22 F7 F5 68 2D CF 72  
000C0: 68 3D A5 27 54 8A EB 2A 5D F6 73 49 D0 DD 42 6C  
000D0: AB C5 13 00 DA BF 61 20 D2 EB 85 0D 7D B7 77 0A  
000E0: 96 E4 84 1C B5 FC EE A5 46 C8 92 83 F2 CE 95 04  
000F0: 08 FB F3 9D 10 E8 00 AF 70

Record layer message:

type: 16  
version:  
major: 03  
minor: 03  
length: 00F9



fragment:

100000F53081F23081EF30280420D622  
D167A5642E29525A295CB9F28F96F28B  
0EFAA7D3A2BEE149B01178C2DFD50404

ABC51300DABF6120D2EB850D7DB7770A  
96E4841CB5FCEEA546C89283F2CE9504  
08FBF39D10E800AF70

```
00000: 16 03 03 00 F9 10 00 00 F5 30 81 F2 30 81 EF 30
00010: 28 04 20 D6 22 D1 67 A5 64 2E 29 52 5A 29 5C B9
00020: F2 8F 96 F2 8B 0E FA A7 D3 A2 BE E1 49 B0 11 78
00030: C2 DF D5 04 04 4C 93 36 57 A0 81 C2 06 09 2A 85
00040: 03 07 01 02 05 01 01 A0 81 AA 30 21 06 08 2A 85
00050: 03 07 01 01 01 02 30 15 06 09 2A 85 03 07 01 02
00060: 01 02 01 06 08 2A 85 03 07 01 01 02 03 03 81 84
00070: 00 04 81 80 FB 4B F8 AB 9F 71 A7 A6 62 57 0C 77
00080: C3 39 61 DD 60 FC 3C 15 95 01 B5 D2 23 B3 B3 A1
00090: B3 15 A8 49 DC 70 81 A0 AD 59 E5 E5 82 48 22 F6
000A0: E8 6B EF 2A FE 5B D9 7F 2D 3B E4 93 E4 37 C7 BC
000B0: 81 B3 9C 4B D0 FB 94 01 2E AF 7A 0D 64 C4 22 F7
000C0: F5 68 2D CF 72 68 3D A5 27 54 8A EB 2A 5D F6 73
000D0: 49 D0 DD 42 6C AB C5 13 00 DA BF 61 20 D2 EB 85
000E0: 0D 7D B7 77 0A 96 E4 84 1C B5 FC EE A5 46 C8 92
000F0: 83 F2 CE 95 04 08 FB F3 9D 10 E8 00 AF 70
```

-----Client-----

HASH(HM):

```
00000: F8 D6 FE EB 17 64 4D 17 B0 38 36 A6 51 EB 87 69
00010: BD EA A2 D3 EB 18 47 F6 91 91 42 7C 30 D0 17 8E
```

MS:

```
00000: BE 57 46 C8 BB B7 84 7E 97 8F D4 C9 4F 52 34 52
00010: 44 2C 8E B1 72 FD E6 28 1C 18 C5 44 63 B1 F9 4C
00020: 2B D9 81 40 05 41 6D BB 0F 90 A5 7E A4 E0 6B 50
```

Client connection key material

K\_write\_MAC|K\_read\_MAC|K\_write\_ENC|K\_read\_ENC|IV\_write|IV\_read:

```
00000: F3 37 F6 A8 6F F3 1F CA 52 EA 64 7C DE E3 B7 83
00010: 34 AB 77 B5 7F E0 DB 2F C0 C8 71 EC DC AC A5 A8
00020: FB A0 4C 21 32 82 3A 24 96 EF 93 6F 0E BC F3 0E
00030: A0 CB 7E AF 6C A7 94 75 4F 1F 45 B1 77 22 DE B4
00040: 4E 5B C3 2D 44 30 AF 58 93 11 6A CF 81 A3 BE 0C
00050: 90 D2 EA 8E 76 E0 84 07 28 BA F5 E2 B2 F9 40 C0
00060: AE 18 26 7B B6 34 C1 6A 1D 1A C1 24 73 50 95 4B
00070: 2F EE 9B 77 F3 0D 18 D5 54 01 2B 43 78 60 87 0A
00080: D9 21 A8 4B 07 FF 98 AF 8C 82 38 6B 91 FB BA 64
```

-----Server-----

PMSEXP extracted:

```
00000: FB F3 9D 10 E8 00 AF 70 D6 22 D1 67 A5 64 2E 29
00010: 52 5A 29 5C B9 F2 8F 96 F2 8B 0E FA A7 D3 A2 BE
00020: E1 49 B0 11 78 C2 DF D5 4C 93 36 57
```

HASH(r\_c | r\_s):

00000: FB F3 9D 10 E8 00 AF 70 E7 AA 22 C1 10 DA 94 A9  
00010: 9A 58 98 D8 45 27 C7 CB DE C1 1E 53 39 90 6A 1A

K\_EXP:

00000: 3F D9 99 D1 68 4A 15 CC 9B DD 5A 35 06 7A F6 98  
00010: 17 15 00 22 E0 95 54 AC 79 1A 60 F1 61 F5 53 49

PMS:

00000: CE 0D D6 B6 70 42 12 15 2B E4 69 5A 7E 89 F6 4C  
00010: 89 29 A4 0D BF 0A 5A 55 C2 CE 00 2B 06 BA B6 2F

-----Server-----

HASH(HM):

00000: F8 D6 FE EB 17 64 4D 17 B0 38 36 A6 51 EB 87 69  
00010: BD EA A2 D3 EB 18 47 F6 91 91 42 7C 30 D0 17 8E

MS:

00000: BE 57 46 C8 BB B7 84 7E 97 8F D4 C9 4F 52 34 52  
00010: 44 2C 8E B1 72 FD E6 28 1C 18 C5 44 63 B1 F9 4C  
00020: 2B D9 81 40 05 41 6D BB 0F 90 A5 7E A4 E0 6B 50

Client connection key material

K\_read\_MAC|K\_write\_MAC|K\_read\_ENC|K\_write\_ENC|IV\_read|IV\_write:

00000: F3 37 F6 A8 6F F3 1F CA 52 EA 64 7C DE E3 B7 83  
00010: 34 AB 77 B5 7F E0 DB 2F C0 C8 71 EC DC AC A5 A8  
00020: FB A0 4C 21 32 82 3A 24 96 EF 93 6F 0E BC F3 0E  
00030: A0 CB 7E AF 6C A7 94 75 4F 1F 45 B1 77 22 DE B4  
00040: 4E 5B C3 2D 44 30 AF 58 93 11 6A CF 81 A3 BE 0C  
00050: 90 D2 EA 8E 76 E0 84 07 28 BA F5 E2 B2 F9 40 C0  
00060: AE 18 26 7B B6 34 C1 6A 1D 1A C1 24 73 50 95 4B  
00070: 2F EE 9B 77 F3 0D 18 D5 54 01 2B 43 78 60 87 0A  
00080: D9 21 A8 4B 07 FF 98 AF 8C 82 38 6B 91 FB BA 64

-----Client-----

ChangeCipherSpec message:

type: 01

00000: 01

Record layer message:

type: 14

version:

major: 03

minor: 03

length: 0001

fragment: 01

00000: 14 03 03 00 01 01

-----Client-----

**HASH(HM):**

**00000:** F8 D6 FE EB 17 64 4D 17 B0 38 36 A6 51 EB 87 69  
**00010:** BD EA A2 D3 EB 18 47 F6 91 91 42 7C 30 D0 17 8E

**Finished message:**

**msg\_type:** 14  
**length:** 00000C  
**body:**  
**verify\_data:** D3EE1DEA725CD7080C744311

**00000:** 14 00 00 0C D3 EE 1D EA 72 5C D7 08 0C 74 43 11

**Record layer message:**

**type:** 16  
**version:**  
**major:** 03  
**minor:** 03  
**length:** 0014  
**fragment:** 8854A0ED0CCBDAE076FA7D22D763A8D1  
AF701BBB

**00000:** 16 03 03 00 14 88 54 A0 ED 0C CB DA E0 76 FA 7D  
**00010:** 22 D7 63 A8 D1 AF 70 1B BB

-----Server-----

**ChangeCipherSpec message:**

**type:** 01

**00000:** 01

**Record layer message:**

**type:** 14  
**version:**  
**major:** 03  
**minor:** 03  
**length:** 0001  
**fragment:** 01

**00000:** 14 03 03 00 01 01

-----Server-----

**HASH(HM):**

**00000:** 9C 9F C4 E3 32 5B 5F B3 70 B9 94 2A 71 D2 6E F0  
**00010:** 10 71 D8 A5 A1 8F 69 E8 C2 0B 70 CC 90 E9 A9 46

**Finished message:**

**msg\_type:** 14  
**length:** 00000C  
**body:**  
**verify\_data:** D6A2A697E9F23DB0F9017A79

00000: 14 00 00 0C D6 A2 A6 97 E9 F2 3D B0 F9 01 7A 79

Record layer message:

type: 16  
version:  
  major: 03  
  minor: 03  
length: 0014  
fragment: 7BDDBB3C0A6A4A9E302B468CCD5CF786  
          665FFEBC

00000: 16 03 03 00 14 7B DD BB 3C 0A 6A 4A 9E 30 2B 46  
00010: 8C CD 5C F7 86 66 5F FE BC

-----Client-----

Application data:

00000: 48 45 4C 4F 0A

Record layer message:

type: 17  
version:  
  major: 03  
  minor: 03  
length: 0009  
fragment: A8951D9389D1AEFE3B

00000: 17 03 03 00 09 A8 95 1D 93 89 D1 AE FE 3B

-----Server-----

Application data:

00000: 48 45 4C 4F 0A

Record layer message:

type: 17  
version:  
  major: 03  
  minor: 03  
length: 0009  
fragment: 0F368E5CEC86B4F8D7

00000: 17 03 03 00 09 0F 36 8E 5C EC 86 B4 F8 D7

-----Client-----

close\_notify alert:

Alert:  
  level: 01  
  description: 00

00000: 01 00

Record layer message:  
type: 15  
version:  
  major: 03  
  minor: 03  
length: 0006  
fragment: F91FCD98F309

00000: 15 03 03 00 06 F9 1F CD 98 F3 09

-----Server-----

close\_notify alert:  
Alert:  
  level: 01  
  description: 00

00000: 01 00

Record layer message:  
type: 15  
version:  
  major: 03  
  minor: 03  
length: 0006  
fragment: 117B57AD5FED

00000: 15 03 03 00 06 11 7B 57 AD 5F ED

## Contributors

Ekaterina Griboedova  
CryptoPro  
Email: griboedova.e.s@gmail.com

Grigory Sedov  
CryptoPro  
Email: sedovgk@cryptopro.ru

Dmitry Eremin-Solenikov  
Auriga  
Email: dbaryshkov@gmail.com

Lidia Nikiforova  
CryptoPro  
Email: nikiforova@cryptopro.ru

## Authors' Addresses

Stanislav Smyshlyaev (editor)  
CryptoPro

18, Sushevsky val  
Moscow  
127018  
Russian Federation  
Phone: +7 (495) 995-48-20  
Email: svb@cryptopro.ru

Dmitry Belyavskiy  
Cryptocom  
14/2, Kedrova St.  
Moscow  
117218  
Russian Federation  
Email: belldmit@gmail.com

Evgeny Alekseev  
CryptoPro  
18, Sushevsky val  
Moscow  
127018  
Russian Federation  
Email: alekseev@cryptopro.ru