Strong Cryptography in PHP

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About me

- Software Engineer since 1996
- Enjoying PHP since 1999
- PHP Engineer at Zend Technologies, in the Zend Framework Team
- Author of two books on security and cryptography (in italian)
- B.Sc. (Hons) in Computer Science and Economics
- Blog on Programming in PHP: http://www.zimuel.it/blog

Note about the source code

- The source code reported in this presentation is only for teaching purpose. The PHP code reported must be considered only as parts of a complete system.
  DON'T USE IT IN A PRODUCTION ENVIRONMENT!
- In order to implement a secure software using cryptography you need much more information that the one reported in this presentation.
- Our advice is to involve always *cryptography engineers* if you need to implement a secure software, using cryptography, in a production environment.

Strong cryptography

Strong cryptography is the usage of cryptographic systems or components that are considered highly resistant to cryptanalytic attacks

A metric of security?

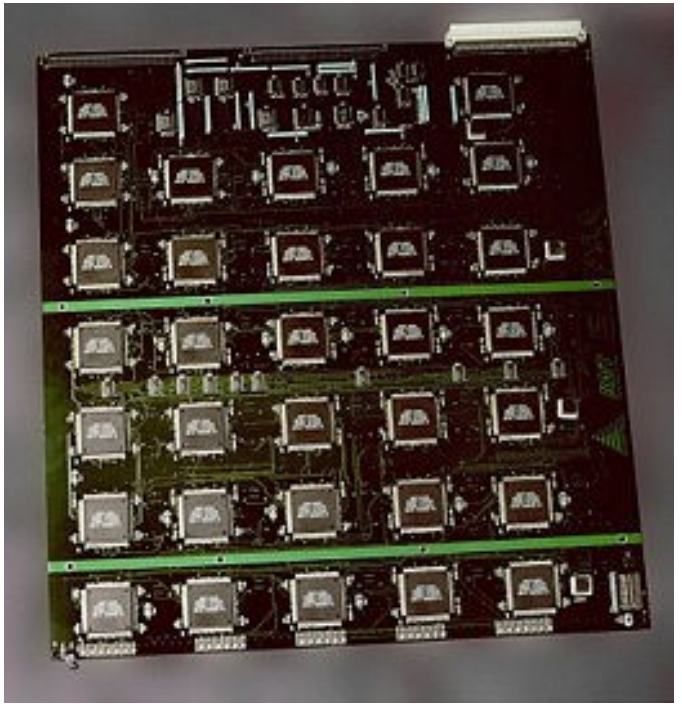
- How we can say that an encryption algorithm is considered highly resistant to cryptanalytic attacks?
- It's difficult to answer to this question. We don't have a simple metric of security.
- We have to consider:
  - Brute forcing attacks
  - Theoretical attacks
  - Implementation attacks

A metric of security? (2)

- **Brute forcing attacks**
  - Space key is 2^n, where n is the byte size of the key. If n=128, K= $3,4 * 10^{38}$
- **Theoretical attacks**
  - Break the encryption with mathematical attacks.
  - Reduce the space key, for AES 256bit, an attack can reduce K to $2^{99.5}$
- **Implementation attacks**
  - Based on the implementation

Is DES still secure?

- **EFF DES cracker** ("Deep Crack") is a computer built by the Electronic Frontier Foundation (EFF) in 1998 to perform a brute force search of DES cipher's key space
- The Deep Crack decrypted a 56 bit DES cryptogram in only 56 hours of work. **In the 1998!**



Examples of strong cryptography

- **Strong:**
  - PGP, OpenPGP, GnuPG
  - AES, Blowfish, Twofish
  - RSA (key ≥ 2048 bit)
- **Not strong:**
  - DES
  - WEP (Wired Equivalent Privacy)
  - SSL 40 bit, international version
  - All the classic ciphers (Enigma, ROT13, Vigenère, etc)

Not only encryption

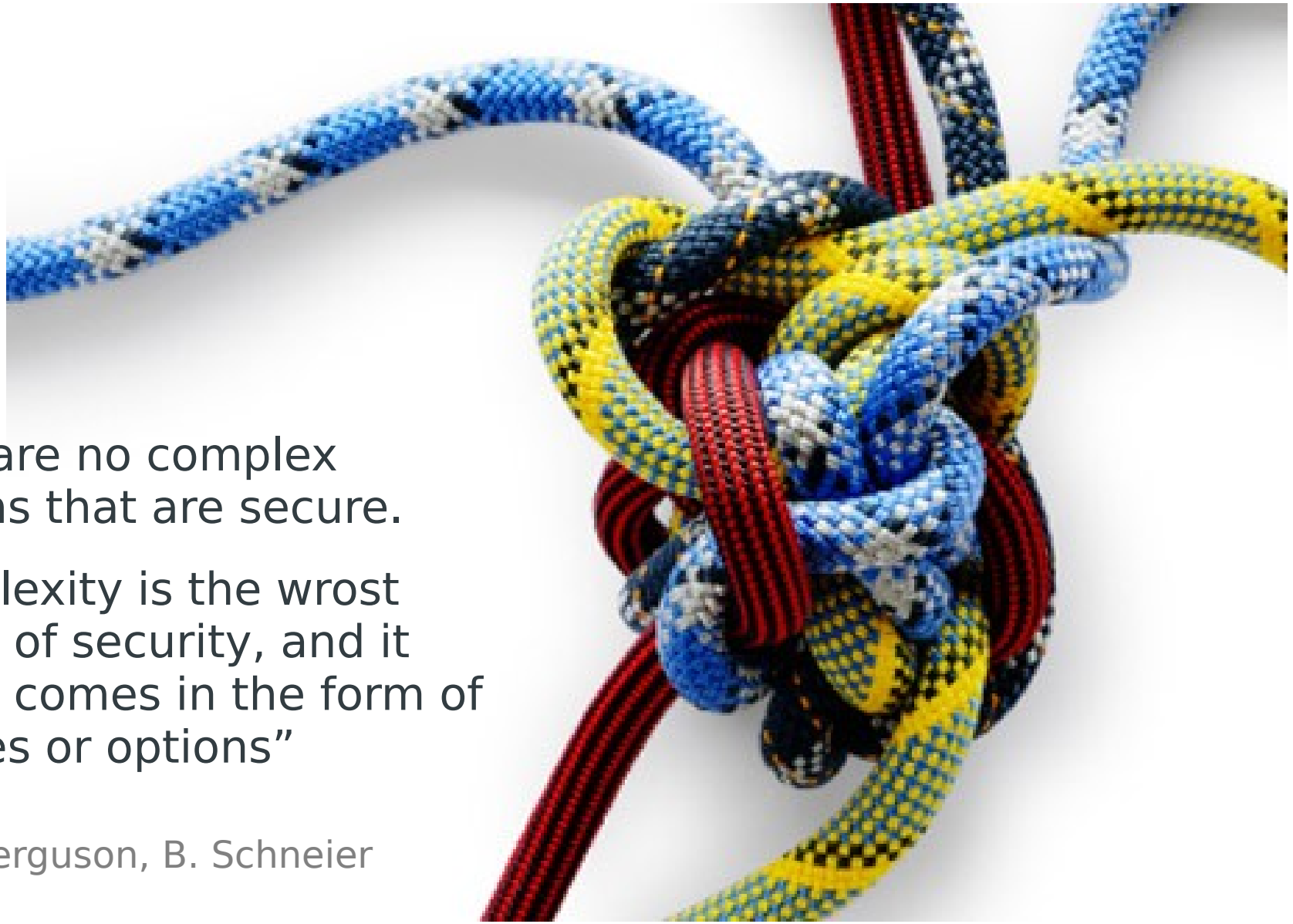
- Strong cryptography is not only related to encryption.
- It can also be used to describe **hashing** and **unique identifier**
- In this usage, the term means **difficult to guess**

Cryptography vs. Security

- Cryptography doesn't means security
- Encryption is not enough
- “Security is a process, not a product”

Bruce Schneier

Complexity vs. Security



- There are no complex systems that are secure.
- “Complexity is the wrost enemy of security, and it always comes in the form of features or options”

N. Ferguson, B. Schneier

Cryptography in PHP

Cryptography in PHP

- crypt()
- Mcrypt
- Hash
- OpenSSL

crypt()

- One-way string hashing
- Support strong cryptography
  - bcrypt, sha-256, sha-512
- PHP 5.3.0 – bcrypt support
- PHP 5.3.2 – sha-256/512

Mcrypt

- Mcrypt is an interface to the mcrypt library, which supports a wide variety of block algorithms
- It support the following encryption algorithms:
  - 3DES, ARCFOUR, BLOWFISH, CAST, DES, ENIGMA, GOST, IDEA (non-free), LOKI97, MARS, PANAMA, RIJNDAEL, RC2, RC4, RC6, SAFER, SERPENT, SKIPJACK, TEAN, TWOFISH, WAKE, XTEA

Hash

- The Hash extension requires no external libraries and is enabled by default as of PHP 5.1.2.
- This extension replace the old mhash extension
- With this extension you can generate hash values or HMAC (Hash-based Message Authentication Code)
- Supported hash algorithms: MD4, MD5, SHA1, SHA256, SHA384, SHA512, RIPEMD, RIPEMD, WHIRLPOOL, GOST, TIGER, HAVAL, etc

OpenSSL

- The OpenSSL extension uses the functions of the OpenSSL project for generation and verification of signatures and for sealing (encrypting) and opening (decrypting) data
- You can use OpenSSL to protect data using public key cryptography with the RSA algorithm.

Use standard algorithms

- AES (RIJNDAEL), FIST 197 standard since 2001
- BLOWFISH
- TWOFISH
- SHA-256, 384, 512
- RSA

Examples and Best practices

How build a key?

- **New key: pseudo-random**
  - Use `openssl_random_pseudo_bytes()` `(PHP 5.3.0)`
  - DO NOT USE rand() or mt_rand()
- **Don't use the user password as a key**
  - Hash with a salt + iteration (stretching)
  - To prevent dictionary based attacks
    Try http://md5.rednoize.com/

Pseudo random key

```php
function pseudoRandomKey($size) {
  if (function_exists('openssl_random_pseudo_bytes')) {
    $rnd = openssl_random_pseudo_bytes($size, $strong);
    if($strong === TRUE)
      return $rnd;
  }
  $sha=''; $rnd='';
  for ($i=0;$i<$size;$i++) {
    $sha= hash('sha256',$sha.mt_rand());
    $char= mt_rand(0,62);
    $rnd.= chr(hexdec($sha[$char].$sha[$char+1]));
  }
  return $rnd;
}
```

Build a key from a user password

- Hash the password with a random salt + stretching

```
$salt= pseudoRandomKey(128);
$hash='';
for ($i=0;$i<HASH_CYCLE_LIMIT;$i++) {
    $hash= hash('sha512',$hash.$salt.$password);
}
```

- HASH_CYCLE_LIMIT depends on the CPU speed, should take between 200 to 1000 ms
  - Intel Core 2 at 2.1Ghz, LIMIT≃ 20'000 (500 ms)

Safely store a password (bcrypt)

- Hash the password using bcrypt (PHP 5.3.0)

```
$salt = substr(str_replace('+', '.',
                base64_encode($salt)), 0, 22);
$hash= crypt($password,'$2a$'.$cost.'$'.$salt);
```

- where **$cost** is the base-2 logarithm of the iteration count (Blowfish). Must be in range 04-31.
- How to check if a password is valid or not:

```
$hash==crypt($password,$hash)
```

Safely store a password (sha256)

```php
function securePassword ($password, $salt) {
    $hash='';
    for ($i=0;$i<SHA_LIMIT_LOOP;$i++) {
        $hash= hash('sha256',$hash.$salt.$password);
    }
    return base64_encode($salt).'$'.$hash;
}
```

- For instance, **$password**= 'thisIsTheSecretPassword' and **$salt**= 'hsjYeg/bxn()%3jdhsGHq0'

  aHNqWWVnL2J4bigpJTNqZGhzR0hxMA==$a9c810e9c722af719adabcf50db8a0b4cd0d14e07eddbb43e5f47bde620a3c13

  Green= salt, Red= encrypted password

Check if a password is valid

```php
function validPassword ($password, $hash) {
    $delimiter= strpos($hash,'$');
    if ($delimiter===false) {
        return false;
    }
    $salt= base64_decode(substr($hash,0,$delimiter));
    $tHash='';
    for ($i=0;$i<SHA_LIMIT_LOOP;$i++) {
        $tHash= hash('sha256',$tHash.$salt.$password);
    }
    return (base64_encode($salt).'$'.$tHash==$hash);
}
```

Example: encrypt with AES (CBC mode)

```
$ivSize= mcrypt_get_iv_size(MCRYPT_RIJNDAEL_128,
                            MCRYPT_MODE_CBC);
$iv= mcrypt_create_iv($ivSize, MCRYPT_RAND);

$key= pseudoRandomKey(16); // 128 bit

$encrypted= mcrypt_encrypt(
    MCRYPT_RIJNDAEL_128,
    $key,
    $data,
    MCRYPT_MODE_CBC,
    $iv
);
```

Example: decrypt with AES (CBC mode)

```
$data= mcrypt_decrypt(
    MCRYPT_RIJNDAEL_128,
    $key,
    $encrypted,
    MCRYPT_MODE_CBC,
    $iv
);
```

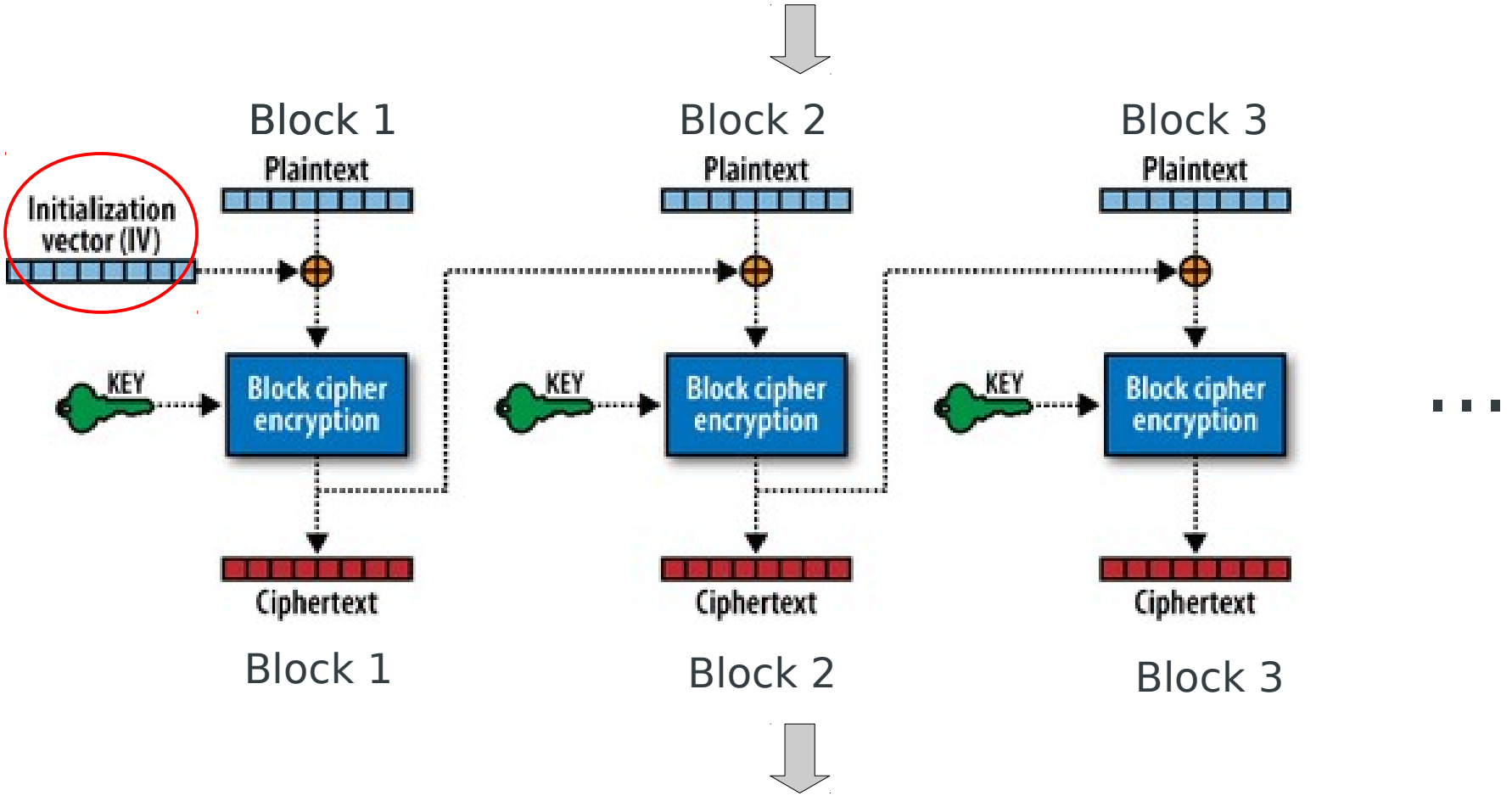
- Question: what is the $iv?

Initialization vector (IV)

- In cryptography, an **Initialization Vector** (IV) is a fixed-size input to a cryptographic primitive that is typically required to be random or pseudorandom
- **The IV is not a secret**, you can send it in plaintext
- Usually IV is stored before the encrypted message

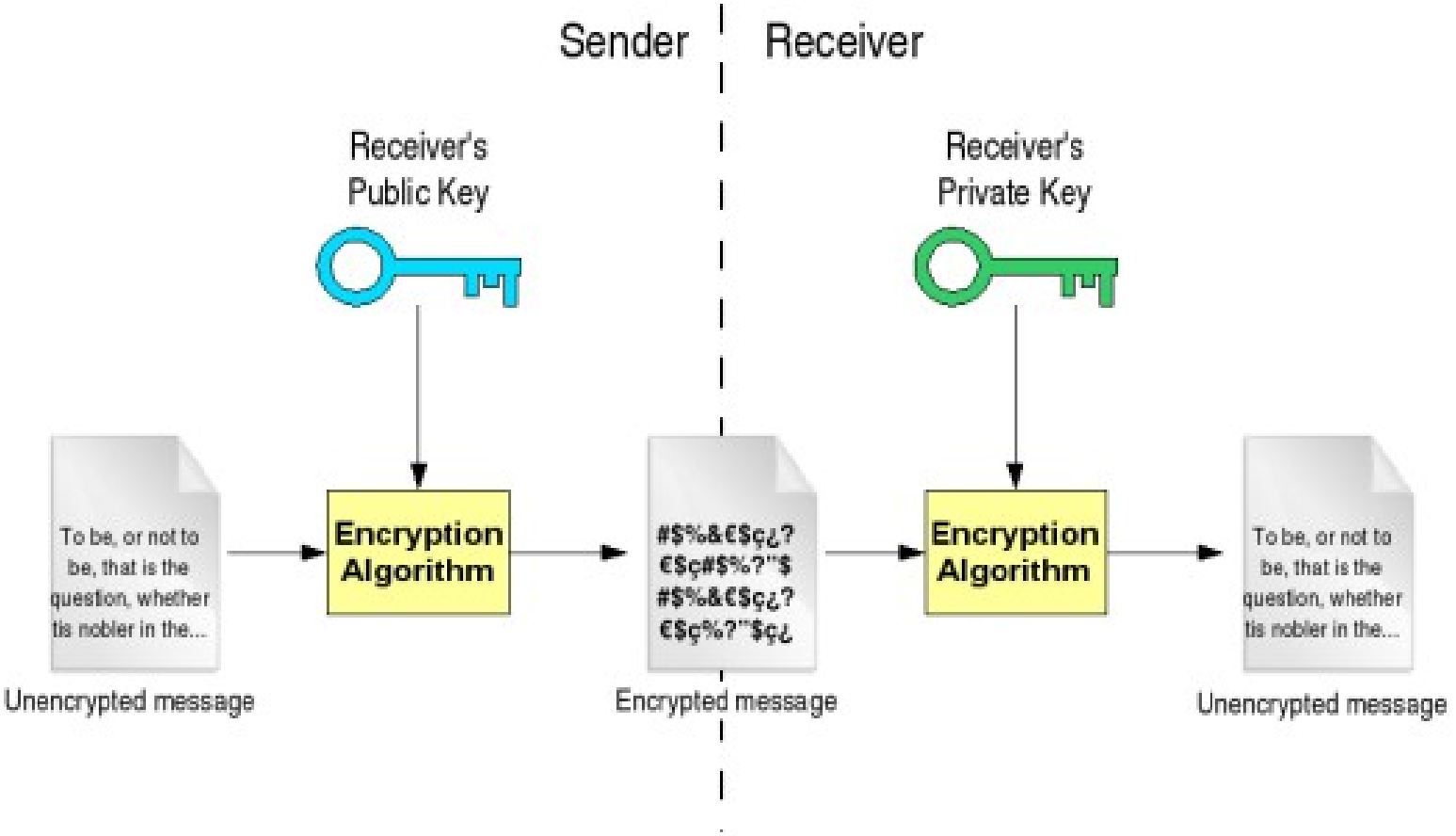
CBC needs IV

The Plaintext (input) is divided into blocks

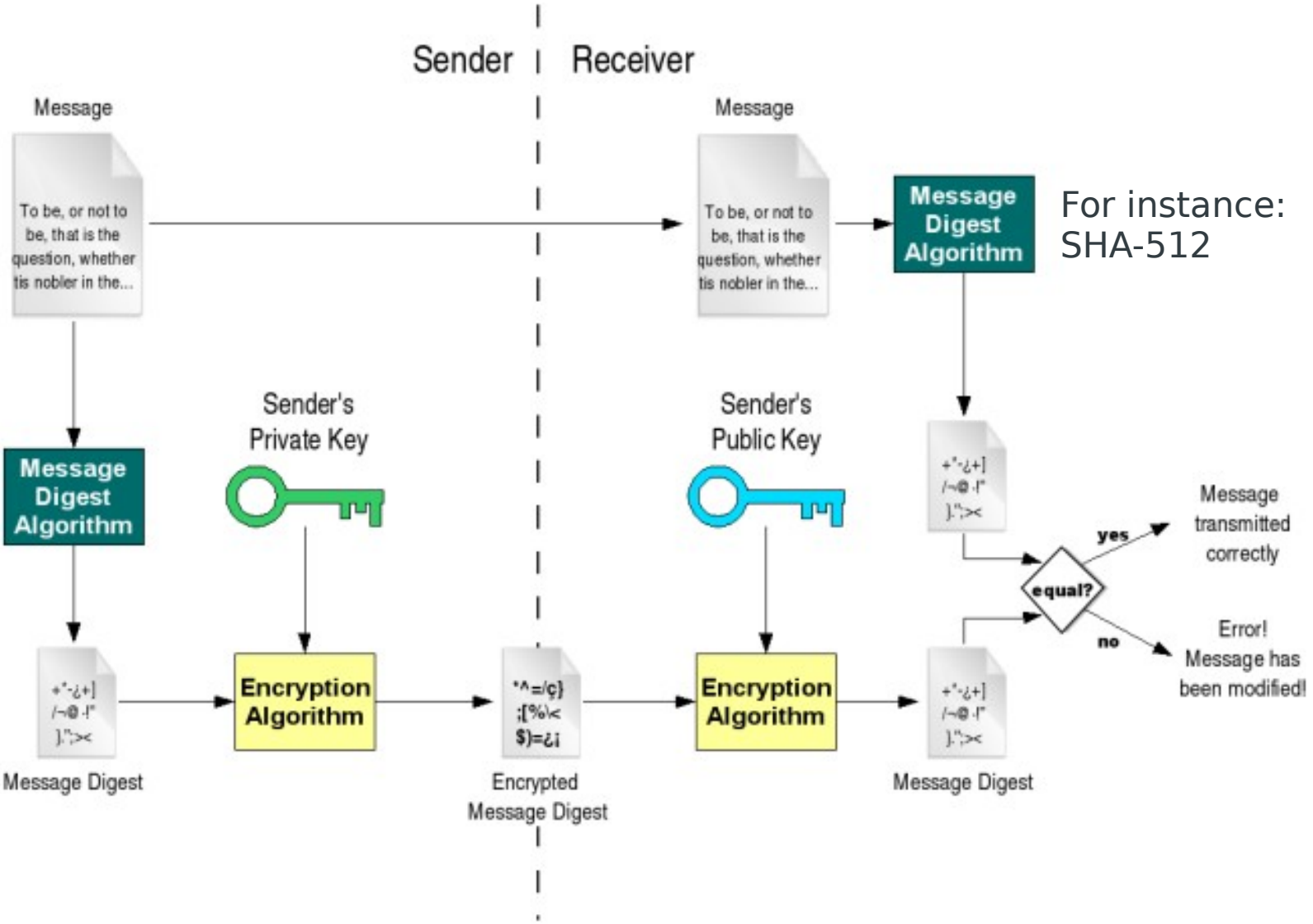


The Ciphertext (output) is the concatenation of the cipher-blocks

Public-key cryptography



Not only encryption: authentication



Generate public and private keys

```php
$privateKey = openssl_pkey_new(array(
    'private_key_bits' => 2048,
    'private_key_type' => OPENSSL_KEYTYPE_RSA
));

openssl_pkey_export_to_file($privateKey,
'/path/to/privatekey', $passphrase);

$keyDetails = openssl_pkey_get_details($privateKey);
file_put_contents('/path/to/publickey',
$keyDetails['key']);
```

Encrypt/decrypt using RSA

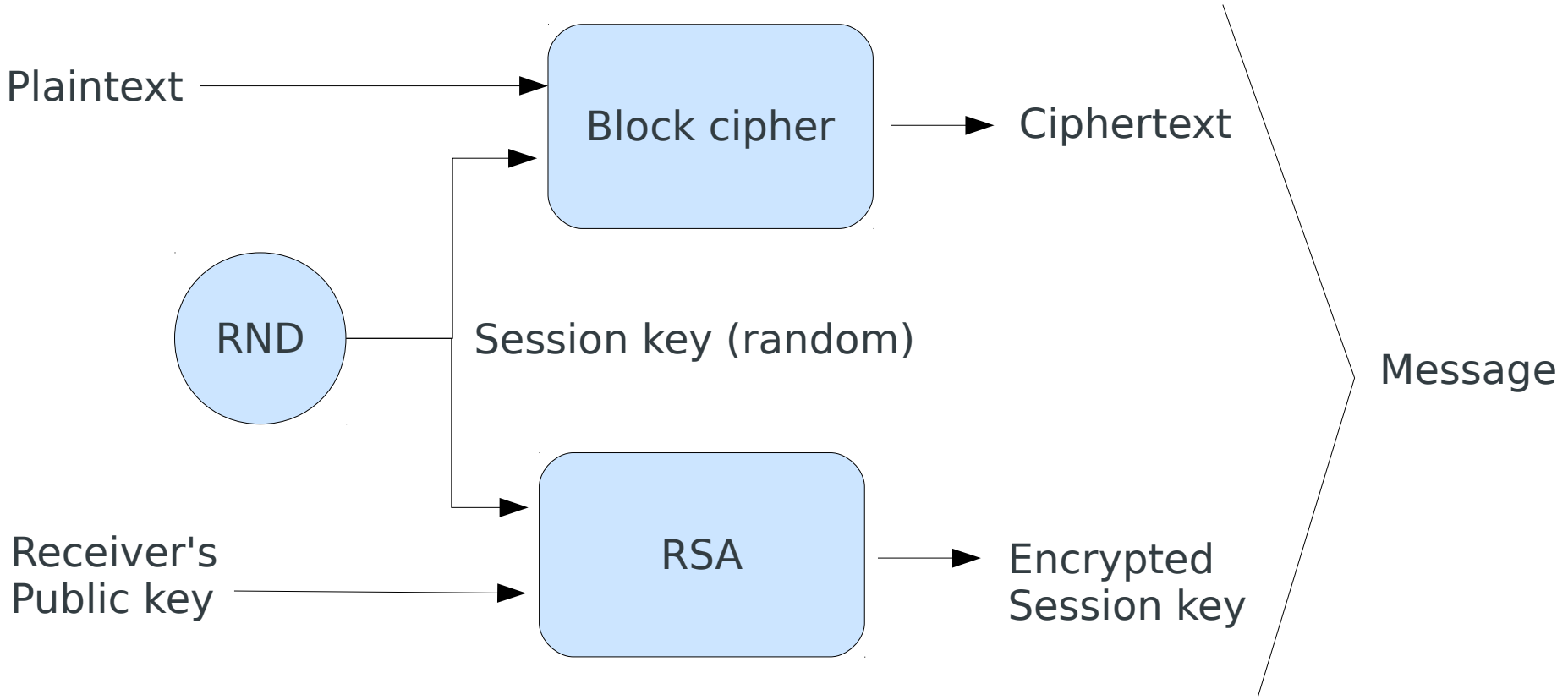
```
// encrypt
$pubKey= openssl_pkey_get_public('pubkeyfile');
openssl_public_encrypt($plaintext,
                       $encrypted,
                        $pubKey);


// decrypt
$privateKey= openssl_pkey_get_private('privkeyfile',
             $passphrase);
openssl_private_decrypt($encrypted,
                        $plaintext,
                         $privateKey);
```

Public-key cryptography to encrypt data

- In general, the public-key cryptography is not used directly to encrypt data.
- Public-key cryptography is computationally heavy, that means the algorithms are very slow!
- We can use hybrid systems:
  - **public key + block chipers**

Example of hybrid system: PGP



Some resources (books and papers)

- N.Ferguson, B.Schneier, and T. Kohno, “Cryptography Engineering” John Wiley & Sons, 2010
- N. Ferguson, B.Schneier, “Pratical Cryptography” Wiley, 2003
- C. Snyder, M.Southwell, “Pro PHP Security”, Apress, 2005
- Chris Chiflett, “Essential PHP Security”, O'Reilly, 2006
- Norman D. Jorstad, Landgrave T. Smith, Jr. “Cryptographic Algorithm Metrics”, Institute for Defense Analyses, 1997
- Z. Benenson, U. Kühn, S.Lucks, “Cryptographic Attack Metrics” Dependability Metrics 2005

Some resources (web)

- PHP Cryptography Extensions, http://www.php.net/manual/en/refs.crypto.php
- crypt(), http://nl.php.net/manual/en/function.crypt.php
- Cracking MD5 and SHA-1, http://md5.rednoize.com/
- A Guide to Cryptography in PHP, http://www.devx.com/webdev/Article/37821
- How To Safely Store A Password, http://codahale.com/how-to-safely-store-a-password/
- Zimuel's blog, Strong Cryptography in PHP
- Zimuel's blog, Encrypt Session data in PHP

Thank you!

- **Twitter:**
  - **@ezimuel**
- **Blog:**
  - **http://www.zimuel.it/blog**
- **GitHub:**
  - **https://github.com/ezimuel**

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- TotalFail.blogspot.com
- Windows Azure: Building a Secure Backup System
- Borja Sotomayor “Globus Toolkit 4 Programmer's Tutorial”

Questions?