PV181 Laboratory of security and applied cryptography

Seminar 13:
Java Crypto Architecture / Java Crypto Extensions

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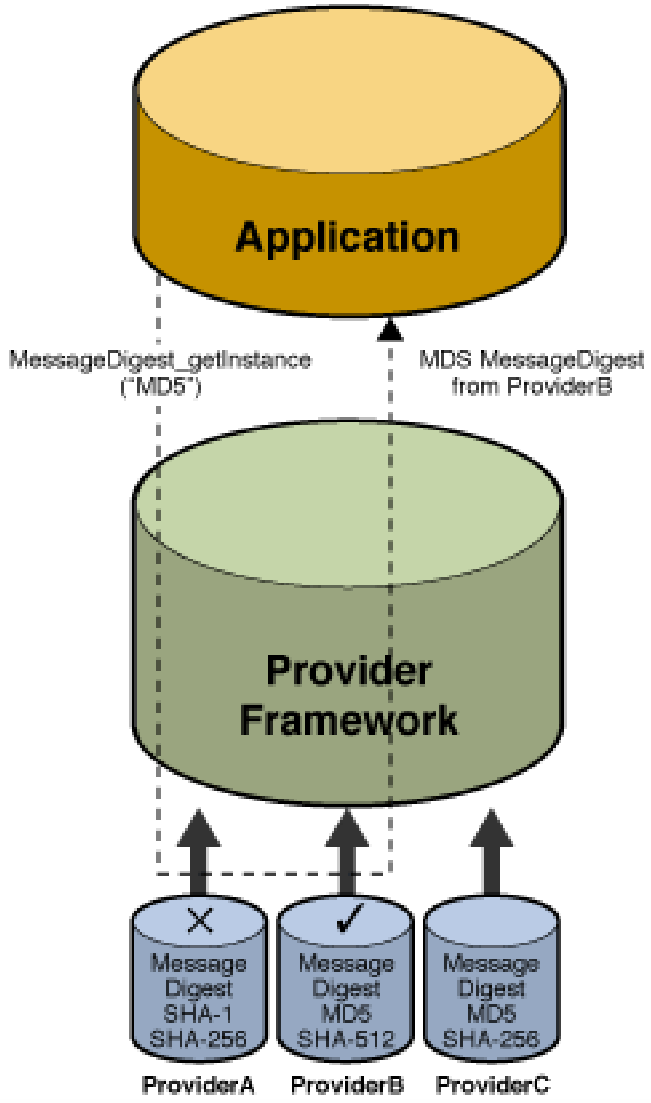
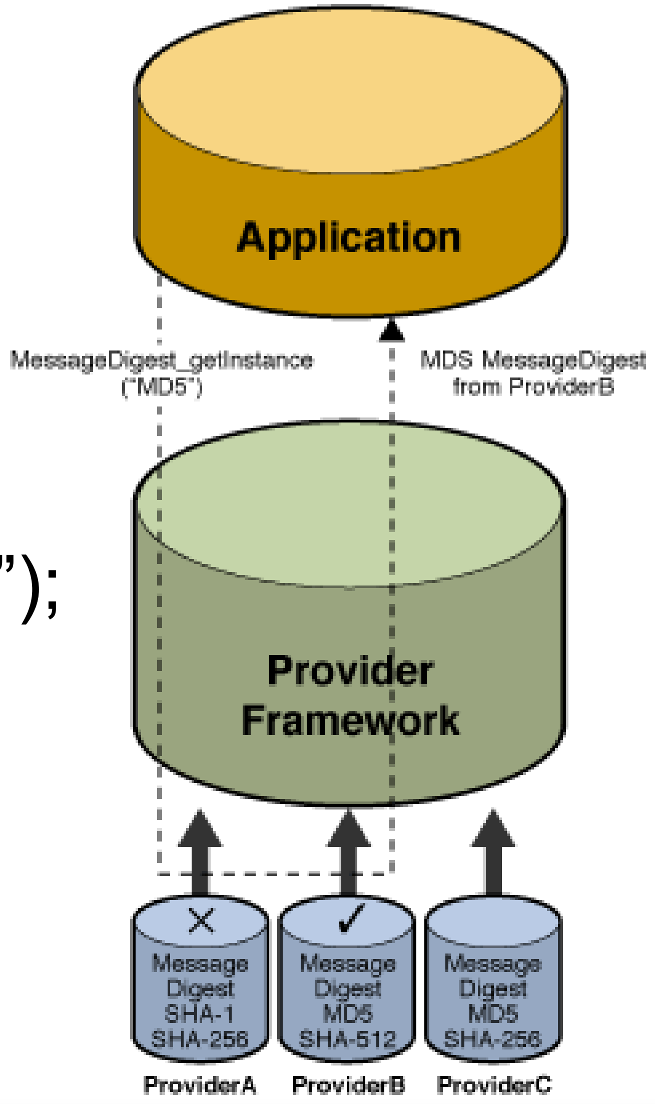
CROCS
Centre for Research on Cryptography and Security

Provider architecture


Application
MessageDigest.getInstance ("MD5")
MD5 MessageDigest from ProviderB
Provider Framework
Message Digest SHA-1 SHA-256
Message Digest MD5 SHA-512
Message Digest MD5 SHA-256
ProviderA
ProviderB
ProviderC

Provider architecture

MessageDigest.
getInstance("MD5");



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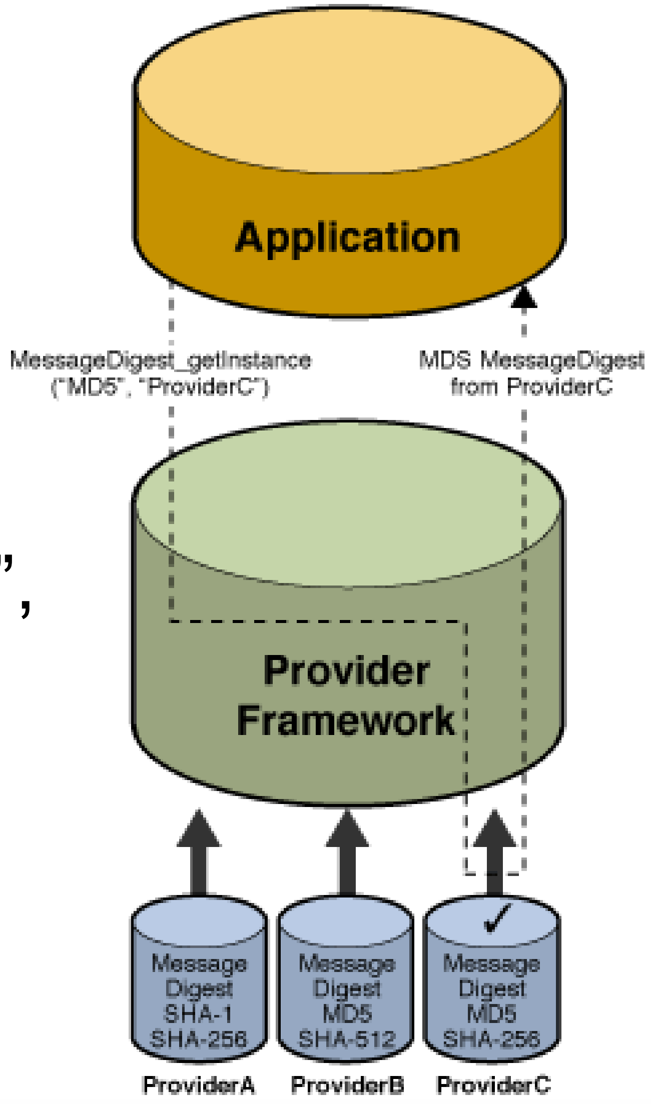
Message Digest MD5 SHA-512
Message Digest MD5 SHA-256
ProviderA
ProviderB
ProviderC

Provider architecture

MessageDigest.
getInstance(“MD5”,
“ProviderC”);



JCA

- java.security.*
  - SecureRandom - PRNG
  - MessageDigest – SHA256, MD5, ...
  - Signature – RSA, DSA
  - KeyStore – PKCS12
  - KeyPairGenerator, KeyFactory, CertificateFactory,

JCE

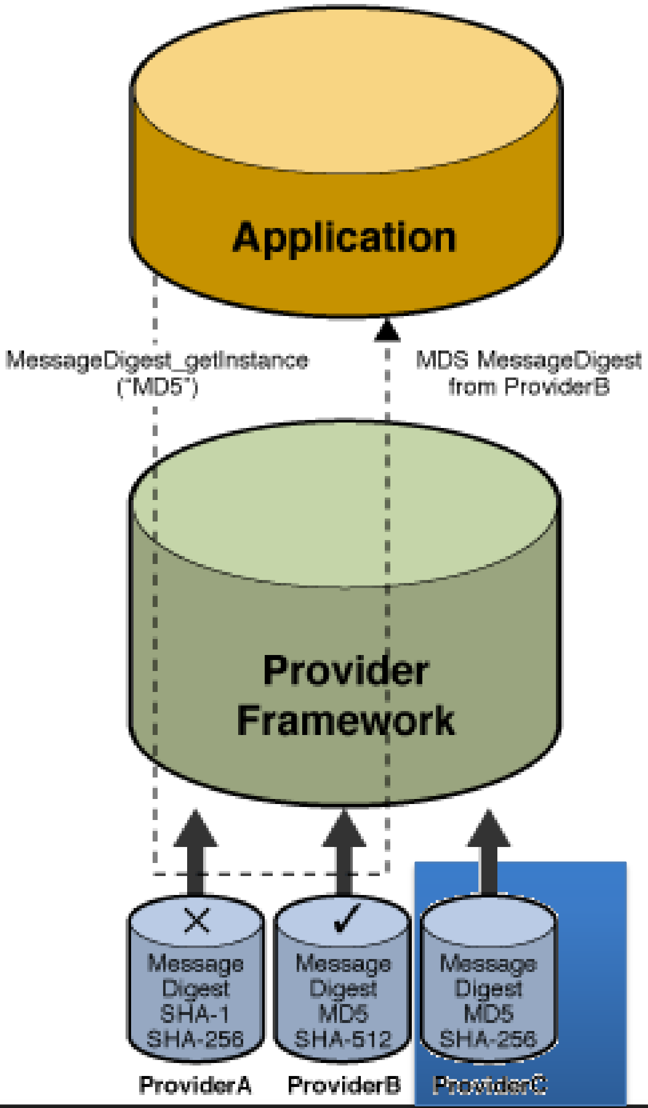
- javax.crypto.*
  - Cipher – AES, RSA, ElGamal, RC4, Salsa20
  - Mac – HMACWithSHA256
  - KeyGenerator

Provider architecture

- Implementation independence
- Implementation interoperability
- Algorithm extensibility

Bouncy Castle

Bouncy Castle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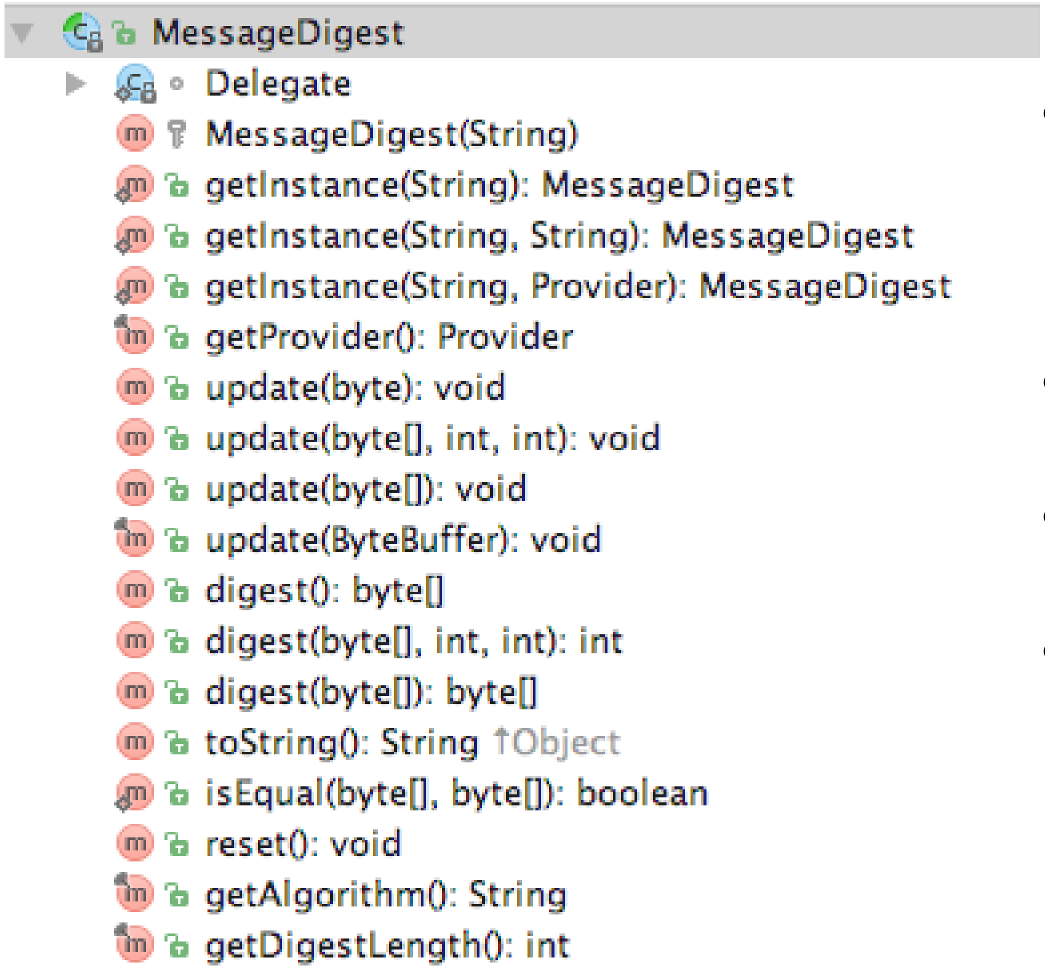
MD5 MessageDigest from ProviderB
Provider Framework
Message Digest SHA-1 SHA-256
Message Digest MD5 SHA-512
Message Digest MD5 SHA-256
ProviderA
ProviderB
ProviderC

BouncyCastle

Bouncy Castle

- Implements a LOT OF ciphers, cipher suites, algorithms, modes, ASN.1, PEM, Certs, PQC, …
- Origin: Australian, former advantage (crypto regulations)
- Android

Provider architecture – Engine classes

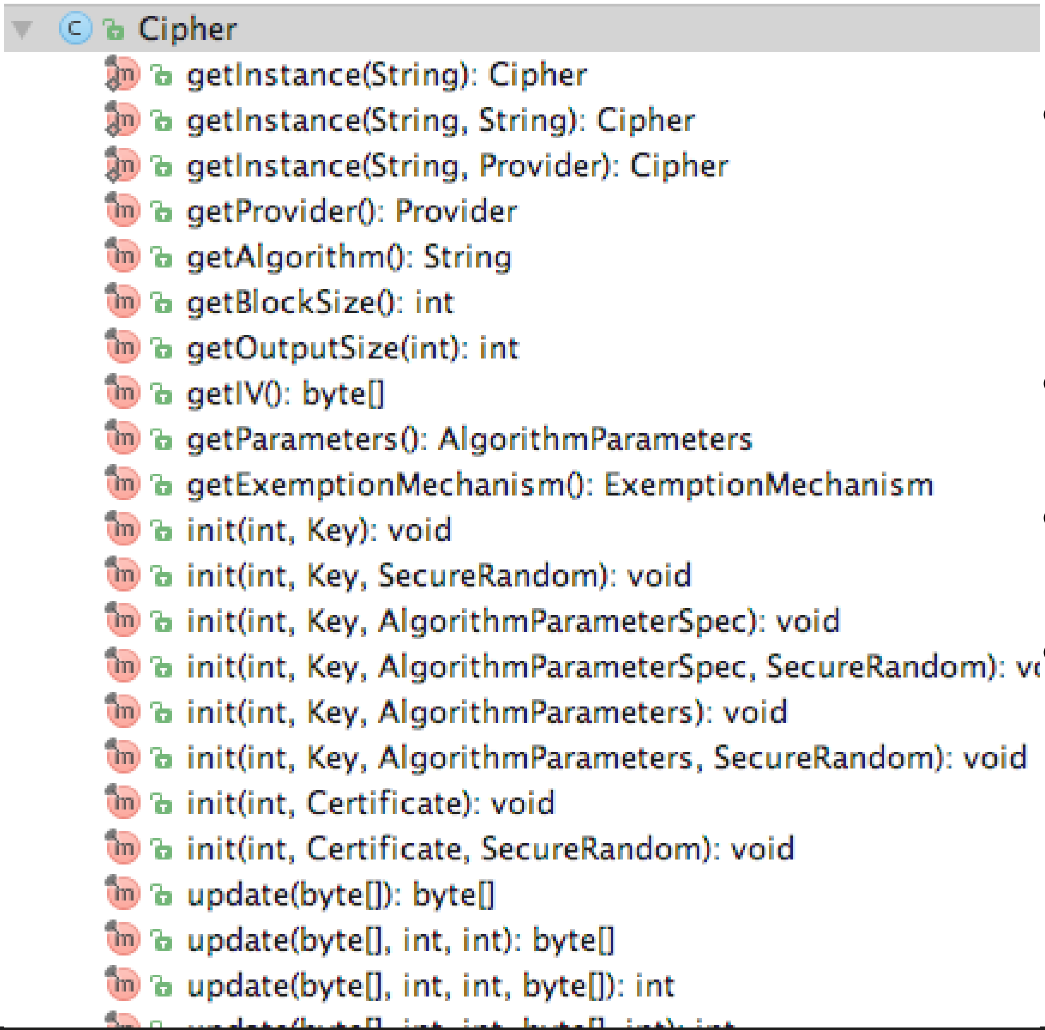


```
MessageDigest
  Delegate
  MessageDigest(String)
  getInstance(String): MessageDigest
  getInstance(String, String): MessageDigest
  getInstance(String, Provider): MessageDigest
  getProvider(): Provider
  update(byte): void
  update(byte[], int, int): void
  update(byte[]): void
  update(ByteBuffer): void
  digest(): byte[]
  digest(byte[], int, int): int
  digest(byte[]): byte[]
  toString(): String ↑Object
  isEqual(byte[], byte[]): boolean
  reset(): void
  getAlgorithm(): String
  getDigestLength(): int
```

- getInstance()

- update()
- digest()
- reset()

Provider architecture – Engine classes

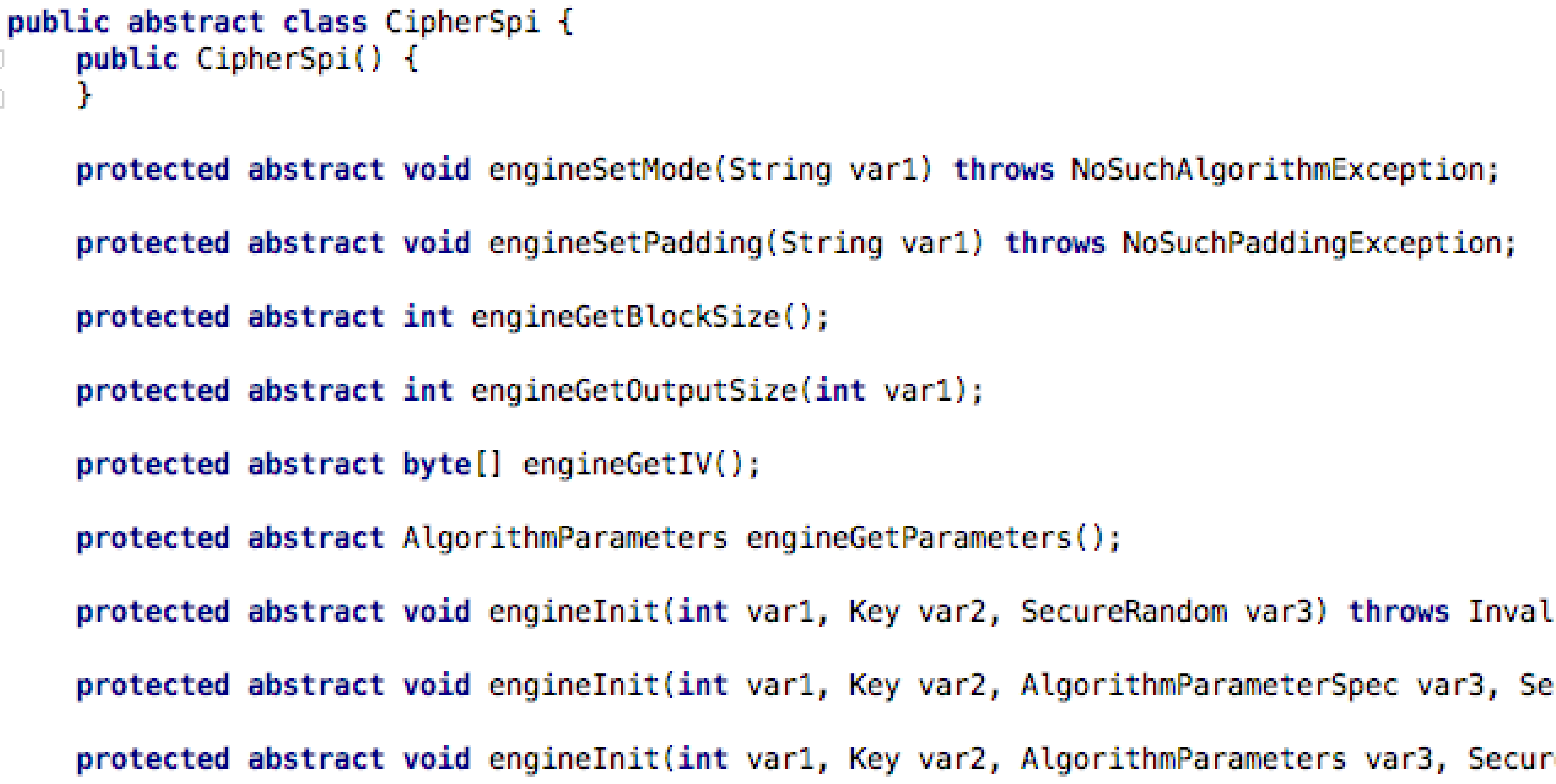


```
Cipher
    getInstance(String): Cipher
    getInstance(String, String): Cipher
    getInstance(String, Provider): Cipher
    getProvider(): Provider
    getAlgorithm(): String
    getBlockSize(): int
    getOutputSize(int): int
    getIV(): byte[]
    getParameters(): AlgorithmParameters
    getExemptionMechanism(): ExemptionMechanism
    init(int, Key): void
    init(int, Key, SecureRandom): void
    init(int, Key, AlgorithmParameterSpec): void
    init(int, Key, AlgorithmParameterSpec, SecureRandom): v
    init(int, Key, AlgorithmParameters): void
    init(int, Key, AlgorithmParameters, SecureRandom): void
    init(int, Certificate): void
    init(int, Certificate, SecureRandom): void
    update(byte[]): byte[]
    update(byte[], int, int): byte[]
    update(byte[], int, int, byte[]): int
    update(byte[], int, int, byte[], int): int
```

- getInstance()

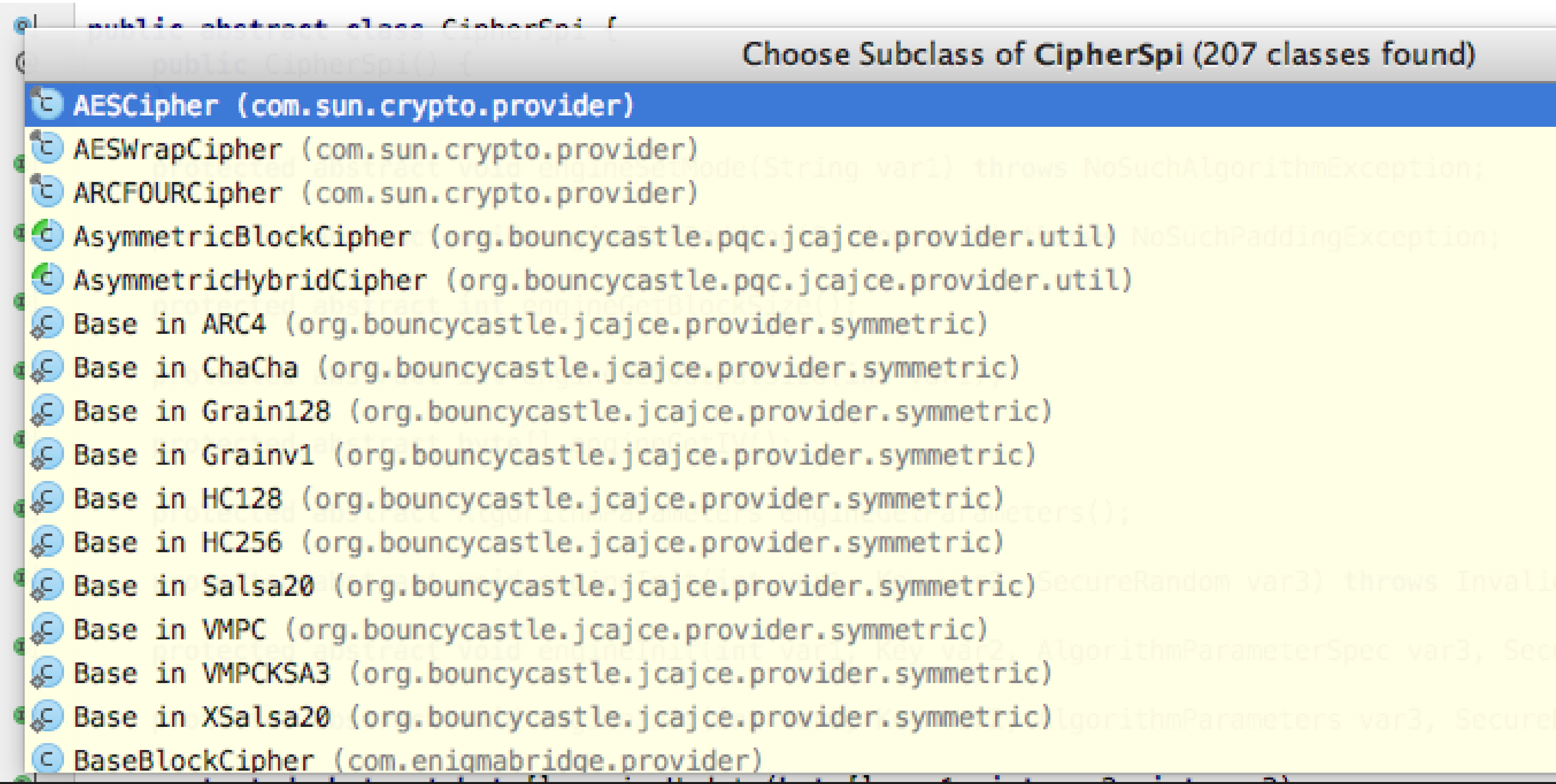
- init()
- update()
- doFinal()

Provider architecture – Spi skeleton



```
public abstract class CipherSpi {
    public CipherSpi() {
    }

    protected abstract void engineSetMode(String var1) throws NoSuchAlgorithmException;

    protected abstract void engineSetPadding(String var1) throws NoSuchPaddingException;

    protected abstract int engineGetBlockSize();

    protected abstract int engineGetOutputSize(int var1);

    protected abstract byte[] engineGetIV();

    protected abstract AlgorithmParameters engineGetParameters();

    protected abstract void engineInit(int var1, Key var2, SecureRandom var3) throws Inval

    protected abstract void engineInit(int var1, Key var2, AlgorithmParameterSpec var3, Se

    protected abstract void engineInit(int var1, Key var2, AlgorithmParameters var3, Secur
```

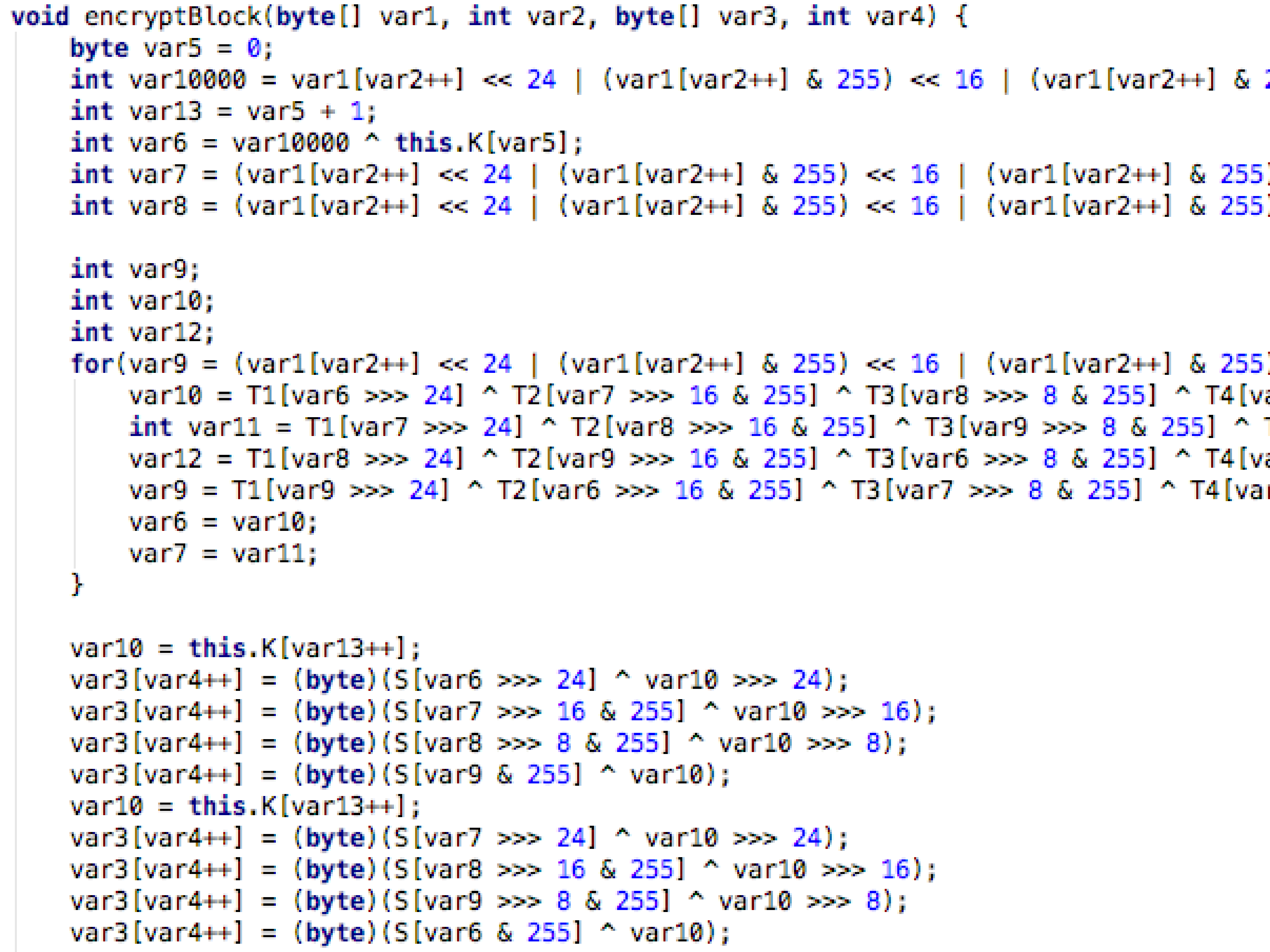
Provider architecture – Spi skeleton



```
public abstract class CipherSpi {
```

Choose Subclass of CipherSpi (207 classes found)

```
AESCipher (com.sun.crypto.provider)
AESWrapCipher (com.sun.crypto.provider)
ARCFOURCipher (com.sun.crypto.provider)
AsymmetricBlockCipher (org.bouncycastle.pqc.jcajce.provider.util)
AsymmetricHybridCipher (org.bouncycastle.pqc.jcajce.provider.util)
Base in ARC4 (org.bouncycastle.jcajce.provider.symmetric)
Base in ChaCha (org.bouncycastle.jcajce.provider.symmetric)
Base in Grain128 (org.bouncycastle.jcajce.provider.symmetric)
Base in Grainv1 (org.bouncycastle.jcajce.provider.symmetric)
Base in HC128 (org.bouncycastle.jcajce.provider.symmetric)
Base in HC256 (org.bouncycastle.jcajce.provider.symmetric)
Base in Salsa20 (org.bouncycastle.jcajce.provider.symmetric)
Base in VMPC (org.bouncycastle.jcajce.provider.symmetric)
Base in VMPCKSA3 (org.bouncycastle.jcajce.provider.symmetric)
Base in XSalsa20 (org.bouncycastle.jcajce.provider.symmetric)
BaseBlockCipher (com.enigmabridge.provider)
```



```
void encryptBlock(byte[] var1, int var2, byte[] var3, int var4) {
    byte var5 = 0;
    int var10000 = var1[var2++] << 24 | (var1[var2++] & 255) << 16 | (var1[var2++] & 2
    int var13 = var5 + 1;
    int var6 = var10000 ^ this.K[var5];
    int var7 = (var1[var2++] << 24 | (var1[var2++] & 255) << 16 | (var1[var2++] & 255
    int var8 = (var1[var2++] << 24 | (var1[var2++] & 255) << 16 | (var1[var2++] & 255

    int var9;
    int var10;
    int var12;
    for(var9 = (var1[var2++] << 24 | (var1[var2++] & 255) << 16 | (var1[var2++] & 255
        var10 = T1[var6 >>> 24] ^ T2[var7 >>> 16 & 255] ^ T3[var8 >>> 8 & 255] ^ T4[va
        int var11 = T1[var7 >>> 24] ^ T2[var8 >>> 16 & 255] ^ T3[var9 >>> 8 & 255] ^ T
        var12 = T1[var8 >>> 24] ^ T2[var9 >>> 16 & 255] ^ T3[var6 >>> 8 & 255] ^ T4[va
        var9 = T1[var9 >>> 24] ^ T2[var6 >>> 16 & 255] ^ T3[var7 >>> 8 & 255] ^ T4[var
        var6 = var10;
        var7 = var11;
    }

    var10 = this.K[var13++];
    var3[var4++] = (byte)(S[var6 >>> 24] ^ var10 >>> 24);
    var3[var4++] = (byte)(S[var7 >>> 16 & 255] ^ var10 >>> 16);
    var3[var4++] = (byte)(S[var8 >>> 8 & 255] ^ var10 >>> 8);
    var3[var4++] = (byte)(S[var9 & 255] ^ var10);
    var10 = this.K[var13++];
    var3[var4++] = (byte)(S[var7 >>> 24] ^ var10 >>> 24);
    var3[var4++] = (byte)(S[var8 >>> 16 & 255] ^ var10 >>> 16);
    var3[var4++] = (byte)(S[var9 >>> 8 & 255] ^ var10 >>> 8);
    var3[var4++] = (byte)(S[var6 & 255] ^ var10);
```

Strong cryptography (History)

- Limits the strength of your crypto
  - the size of the Key
- In old Java versions:
  - AES-256 and RSA-2048 were not available by default
  - Now even PQC is available
- Java Cryptography Extension (JCE) Unlimited Strength Jurisdiction Policy Files

Download NetBeans (maven) project

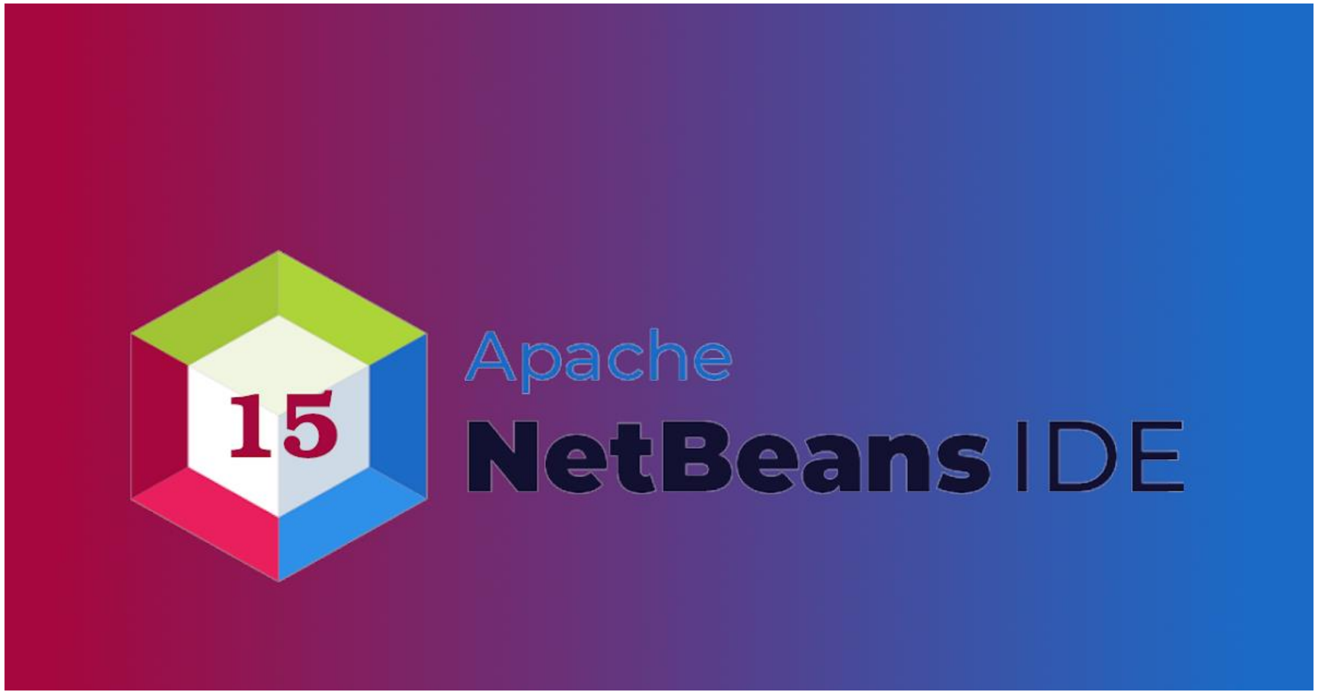
Take from IS:

pv181_mvn.zip

(UPLOADED TODAY!)

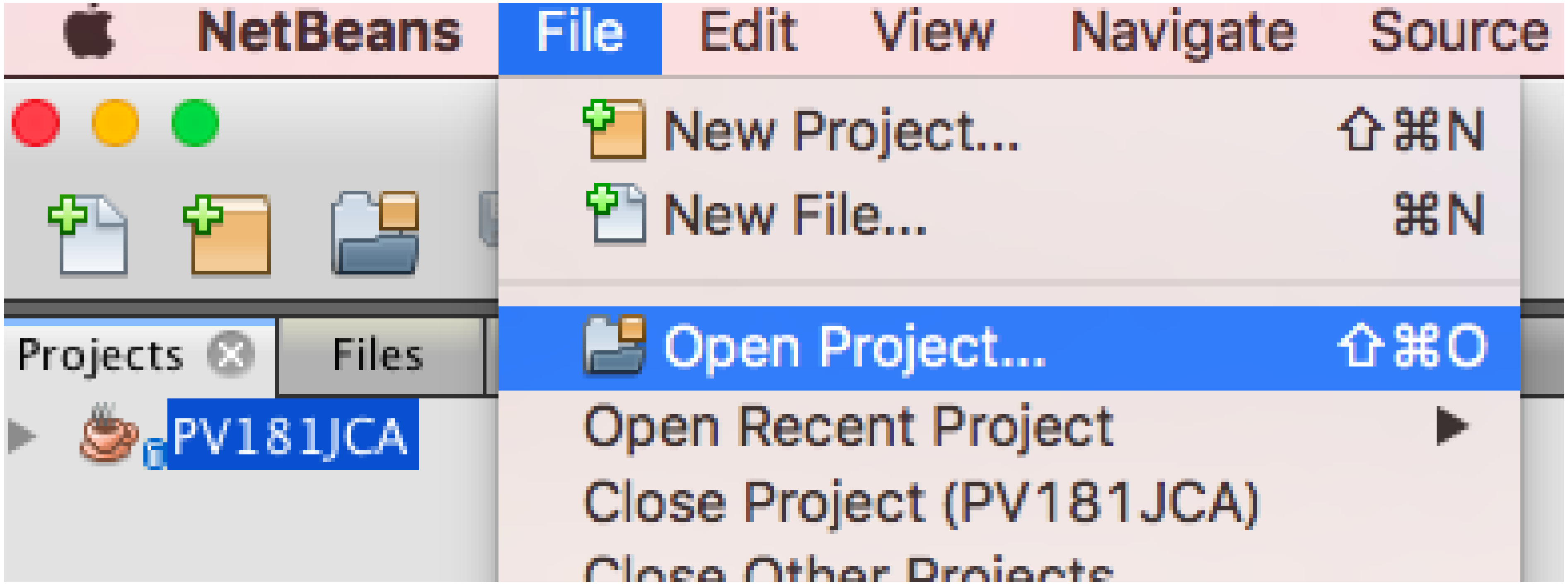
Case sensitive

Please open



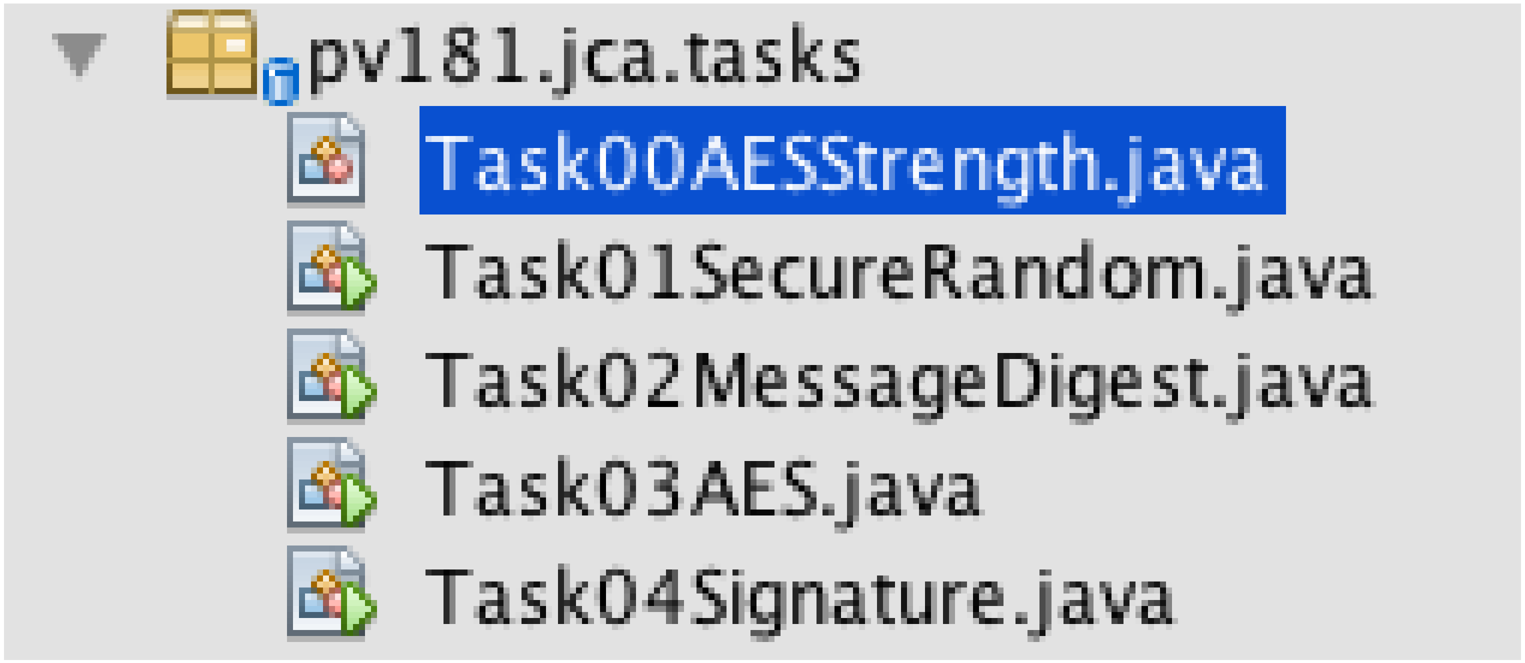
Or Eclipse, CLion etc.

Pls open



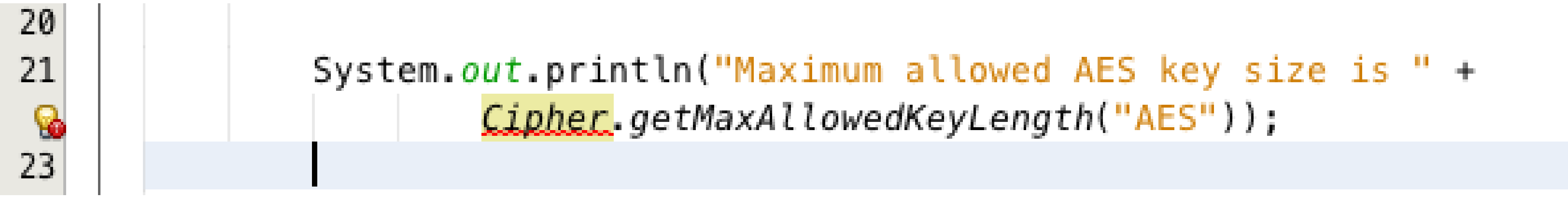
If you have a choice indicate that it is a maven project during import.

Getting started



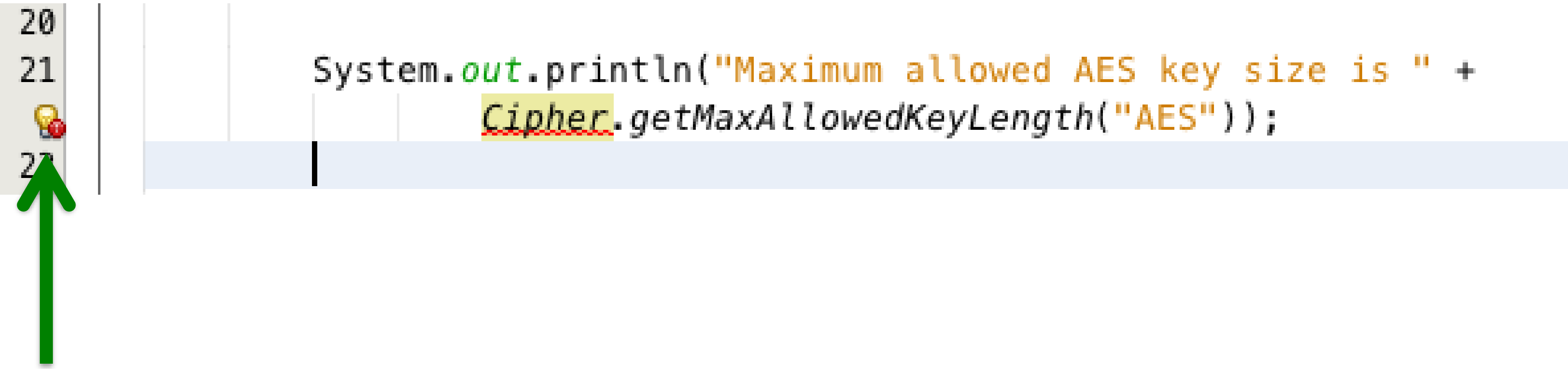
pv181.jca.tasks
Task00AESStrength.java
Task01SecureRandom.java
Task02MessageDigest.java
Task03AES.java
Task04Signature.java

Cipher – import missing



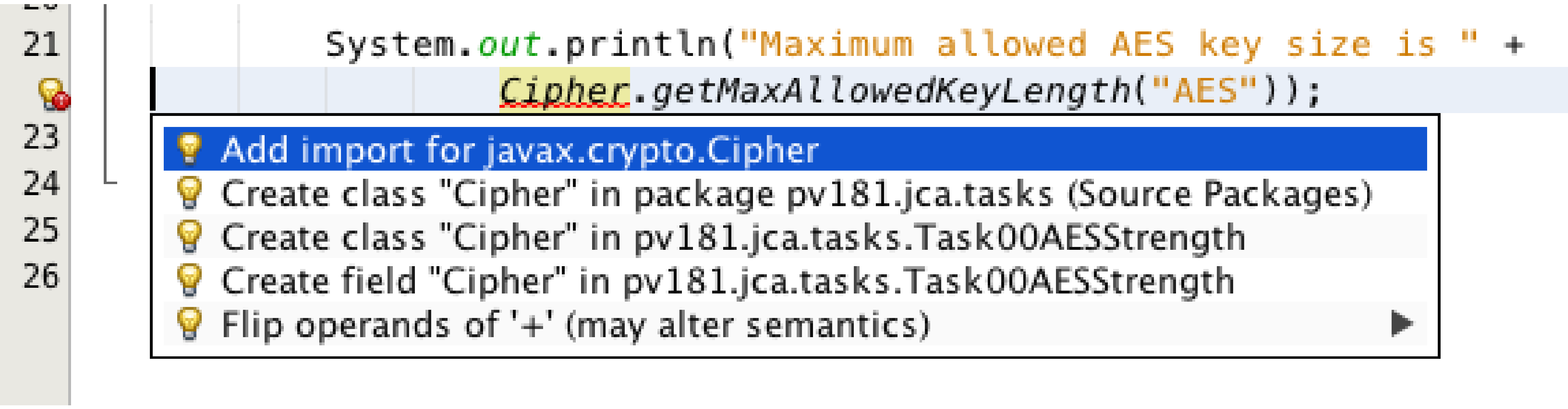
```
        System.out.println("Maximum allowed AES key size is " +
                Cipher.getMaxAllowedKeyLength("AES"));

```

Cipher – import missing



```
System.out.println("Maximum allowed AES key size is " +
        Cipher.getMaxAllowedKeyLength("AES"));
```

Lighbulb helps

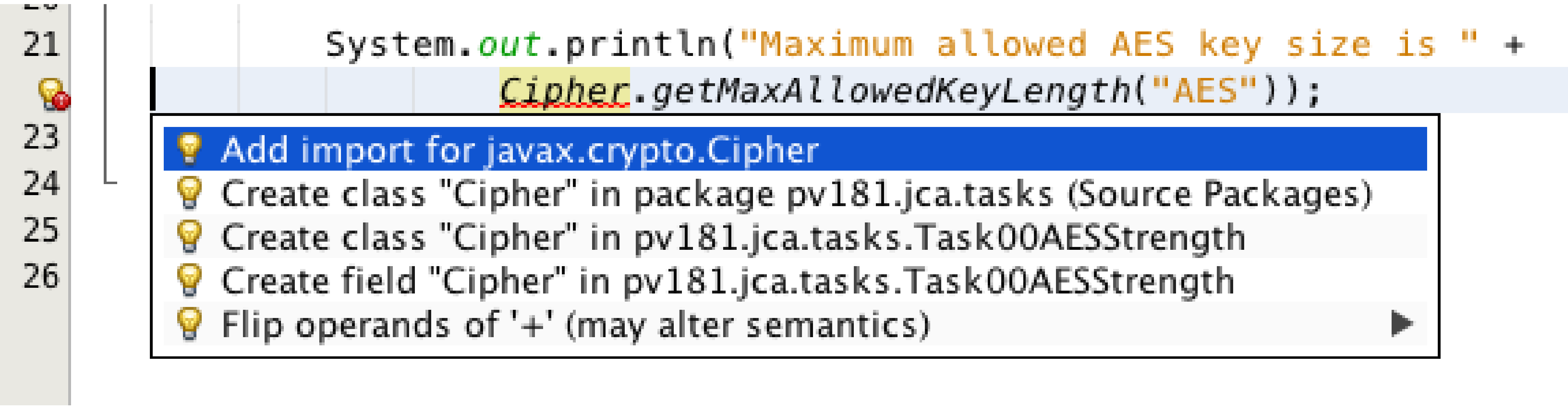


```
        System.out.println("Maximum allowed AES key size is " +
                Cipher.getMaxAllowedKeyLength("AES"));
```

Add import for javax.crypto.Cipher
Create class "Cipher" in package pv181.jca.tasks (Source Packages)
Create class "Cipher" in pv181.jca.tasks.Task00AESStrength
Create field "Cipher" in pv181.jca.tasks.Task00AESStrength
Flip operands of '+' (may alter semantics)

Getting started

CTRL+SHIFT+I



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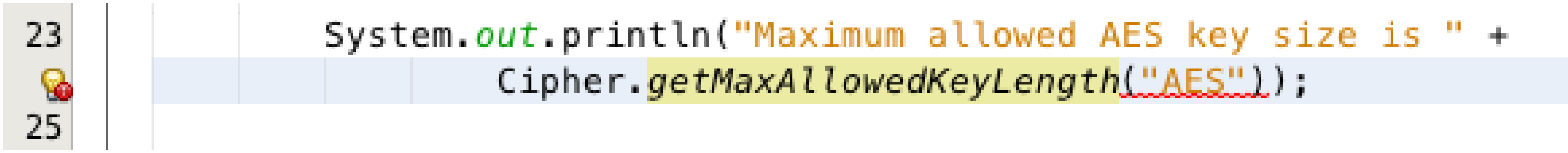
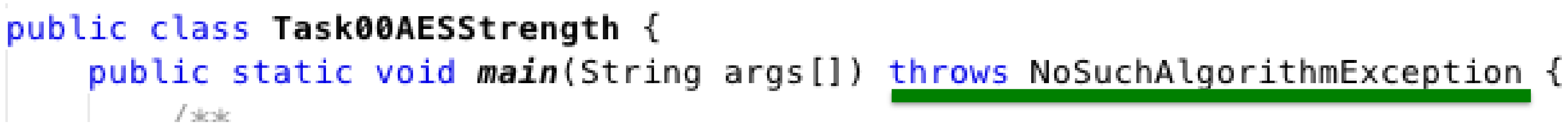
Flip operands of '+' (may alter semantics)

Problem again



```
        System.out.println("Maximum allowed AES key size is " +
                Cipher.getMaxAllowedKeyLength("AES"));

```

Problem again



```
public class Task00AESStrength {
    public static void main(String args[]) throws NoSuchAlgorithmException {
        /**
```

The web

Pls open – the guide

Copy java-course-guide.zip from IS (file name is case sensitive):
Unzip it and open index.html in a browser.
Do, Tasks 0-4.

Task01 - SecureRandom

- SecureRandom rnd = new SecureRandom()
- rnd.nextDouble()
- rnd.nextByte()
- rnd. ....

SecureRandom - solution

- SecureRandom rnd = new SecureRandom();
- rnd.nextBytes(buffer);
- System.out.println(Globals.bytesToHex(buffer));

Task02 - MessageDigest

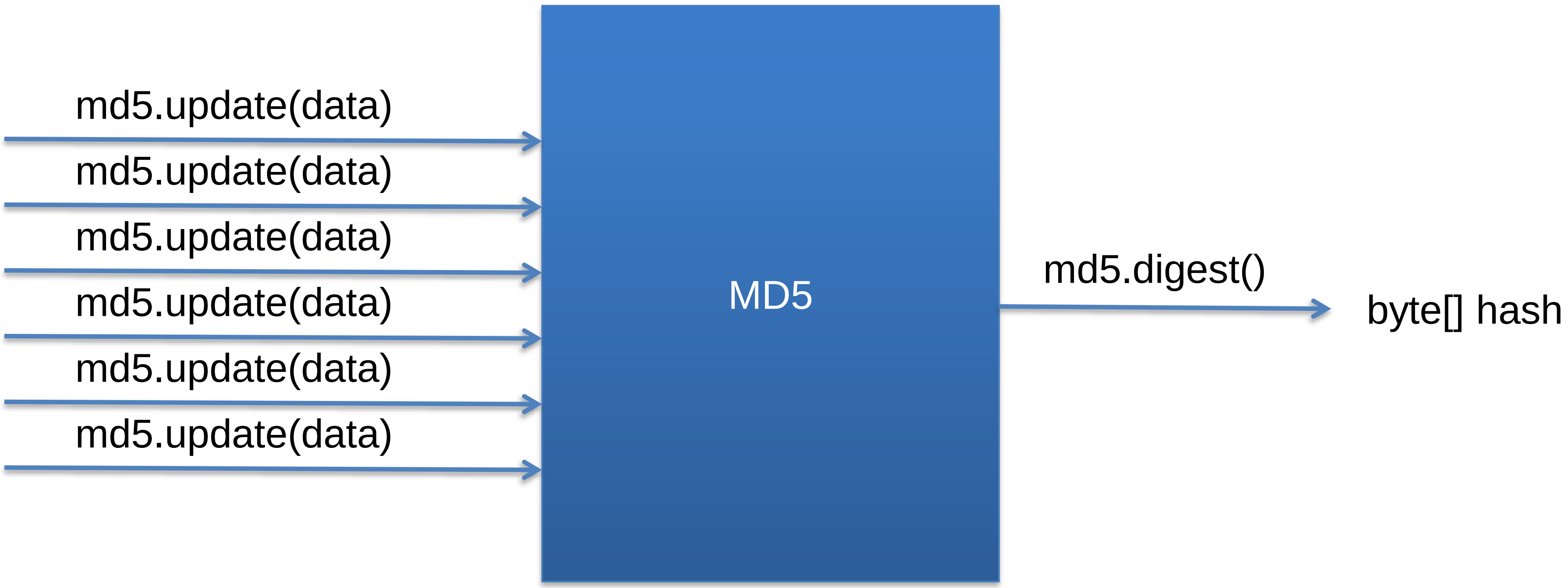
- MessageDigest md5 = MessageDigest.getInstance(“MD5”);

MessageDigest

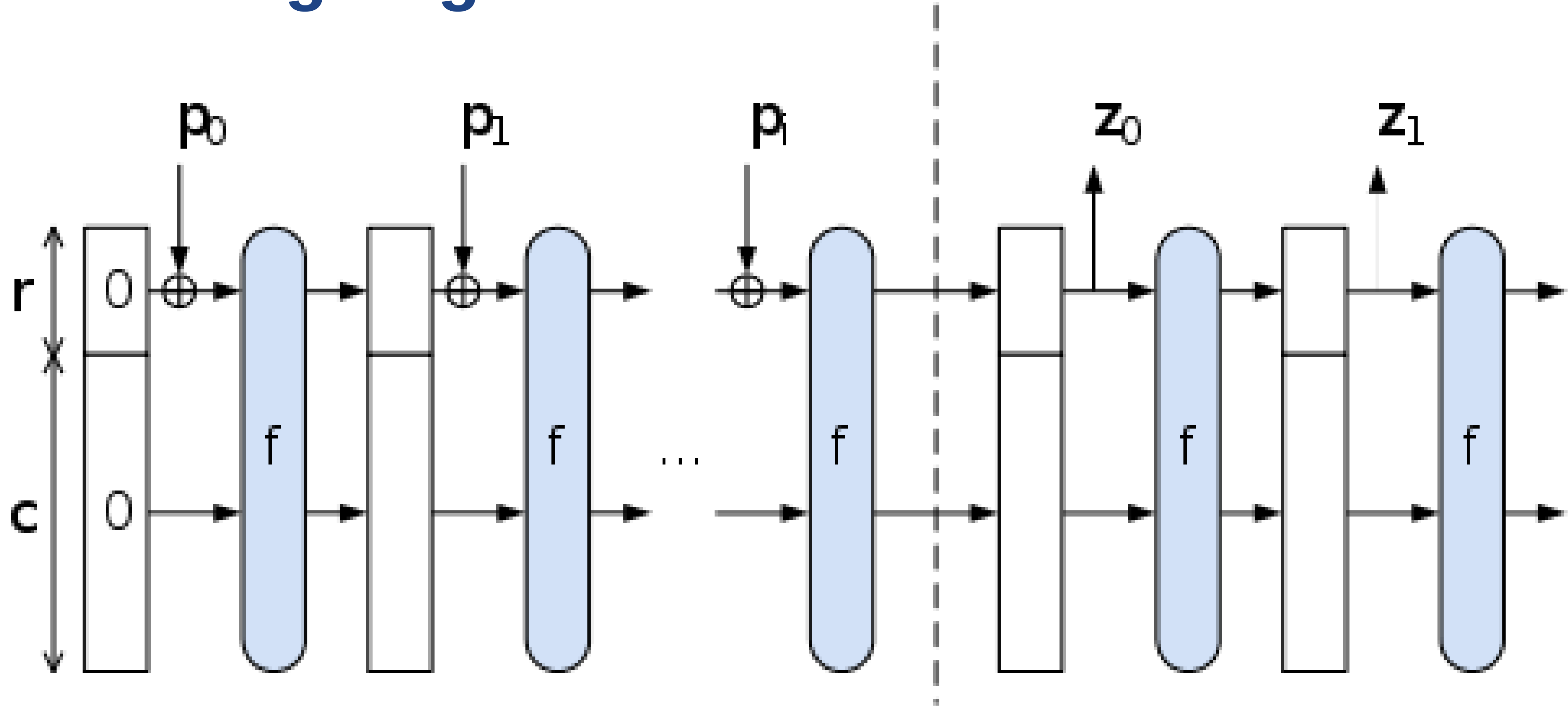
- MessageDigest md5 = MessageDigest.getInstance(“MD5”);

- md5.update(inputBuffer, 0, bytesRead);
- md5.update(inputBuffer, 0, bytesRead);
- md5.update(inputBuffer, 0, bytesRead);
- byte[] md5hash = md5.digest()

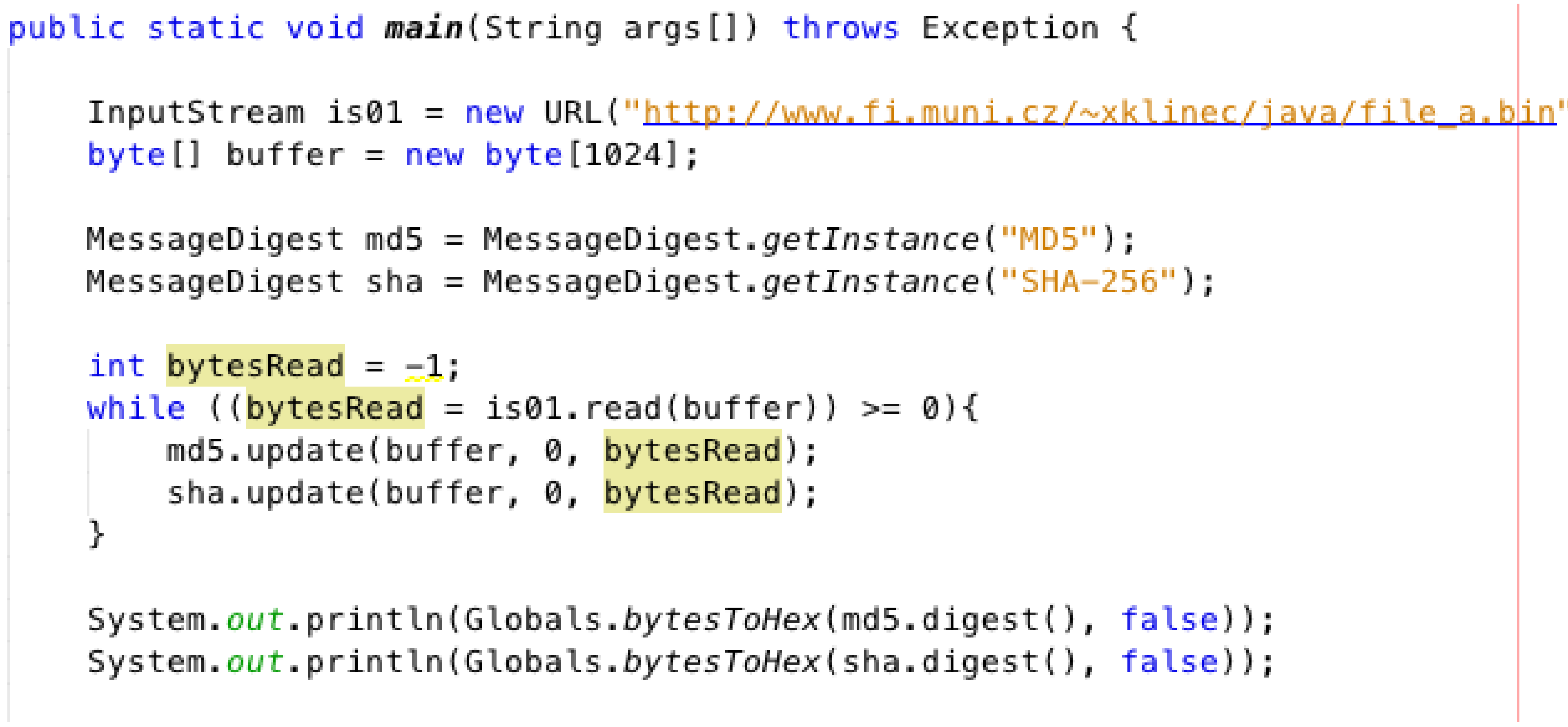
MessageDigest – incremental API



MessageDigest – incremental API



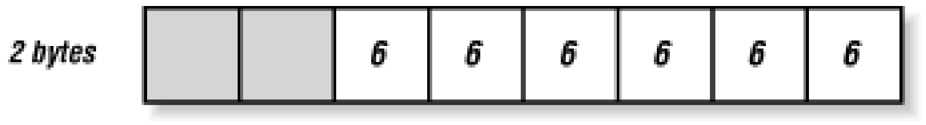
MessageDigest – solution



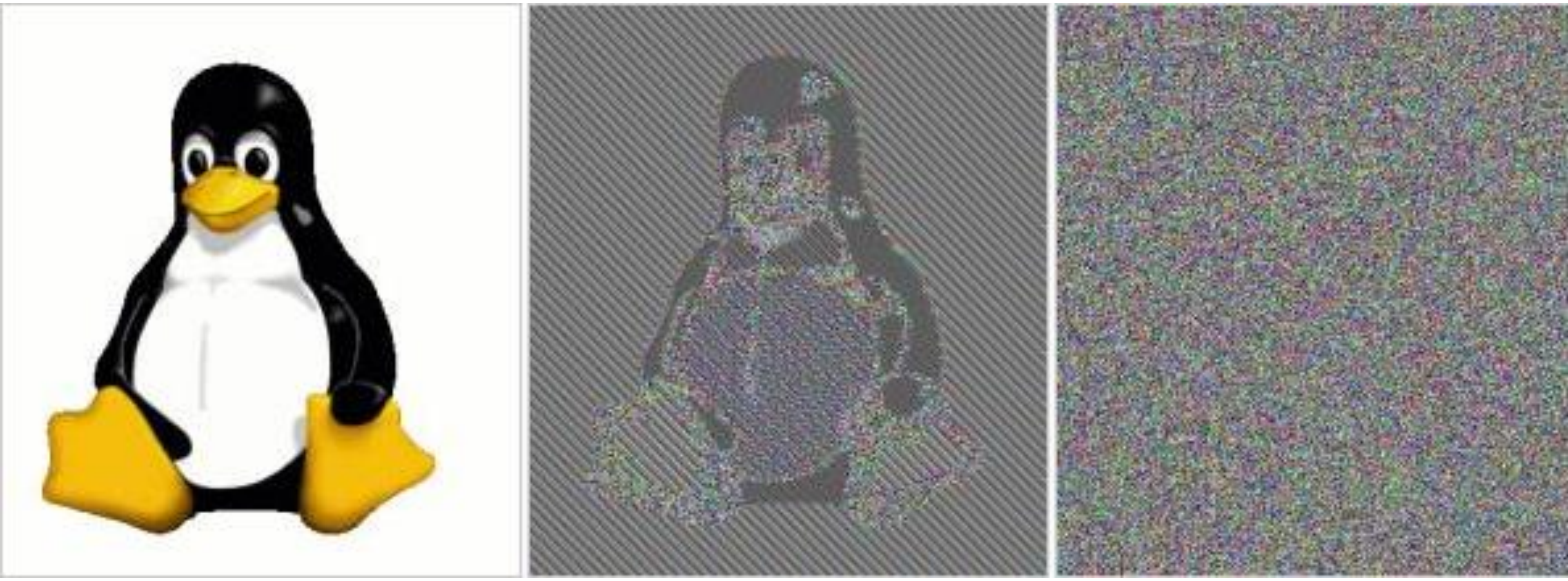
```java
public static void main(String args[]) throws Exception {

    InputStream is01 = new URL("http://www.fi.muni.cz/~xklinec/java/file_a.bin"
    byte[] buffer = new byte[1024];

    MessageDigest md5 = MessageDigest.getInstance("MD5");
    MessageDigest sha = MessageDigest.getInstance("SHA-256");

    int bytesRead = -1;
    while ((bytesRead = is01.read(buffer)) >= 0){
        md5.update(buffer, 0, bytesRead);
        sha.update(buffer, 0, bytesRead);
    }

    System.out.println(Globals.bytesToHex(md5.digest(), false));
    System.out.println(Globals.bytesToHex(sha.digest(), false));
```

Task03 - Cipher

- getInstance(“**algorithm/mode/padding**”);
  - Default mode: ECB
  - Default padding: PKCS5



Cipher



Cipher

- init(mode, key, algorithmParameterSpec)
  - Cipher.DECRYPT_MODE
  - **new** SecretKeySpec(aesKey, **"AES"**)
  - **new** IvParameterSpec(iv)

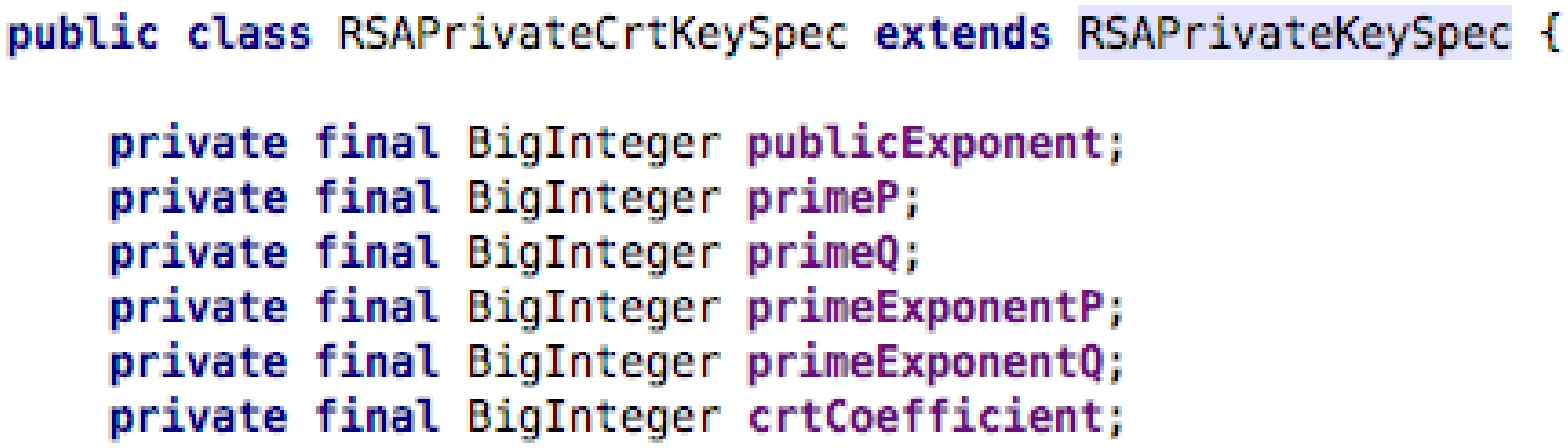
Cipher – Key vs KeySpec

- Key – opaque key, used in engine
  - getAlgoritm(), getEncoded()
- KeySpec – key specification, transport & storage
  - getP(), getQ(), getN()

Cipher – Key vs KeySpec

- SecretKeySpec = Spec & Key in the same time

Cipher – Key vs KeySpec



```
public class RSAPrivateCrtKeySpec extends RSAPrivateKeySpec {

    private final BigInteger publicExponent;
    private final BigInteger primeP;
    private final BigInteger primeQ;
    private final BigInteger primeExponentP;
    private final BigInteger primeExponentQ;
    private final BigInteger crtCoefficient;
```

Cipher – Key vs KeySpec

- Why separated?

Cipher – Key vs KeySpec

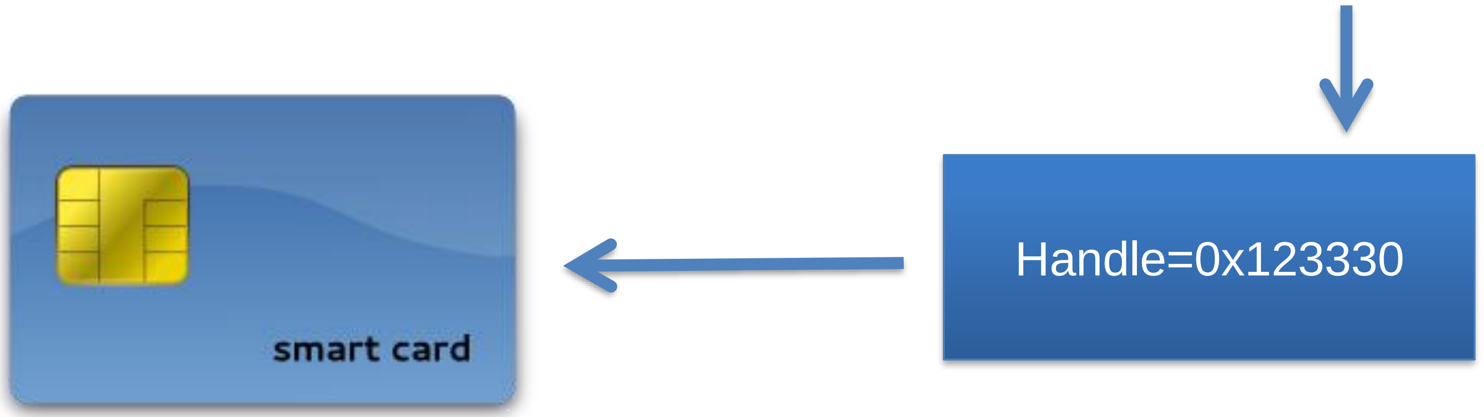
- Why separated?

```
Cipher.init(Cipher.DECRYPT_MODE, key)
```

Cipher – Key vs KeySpec

- Why separated?

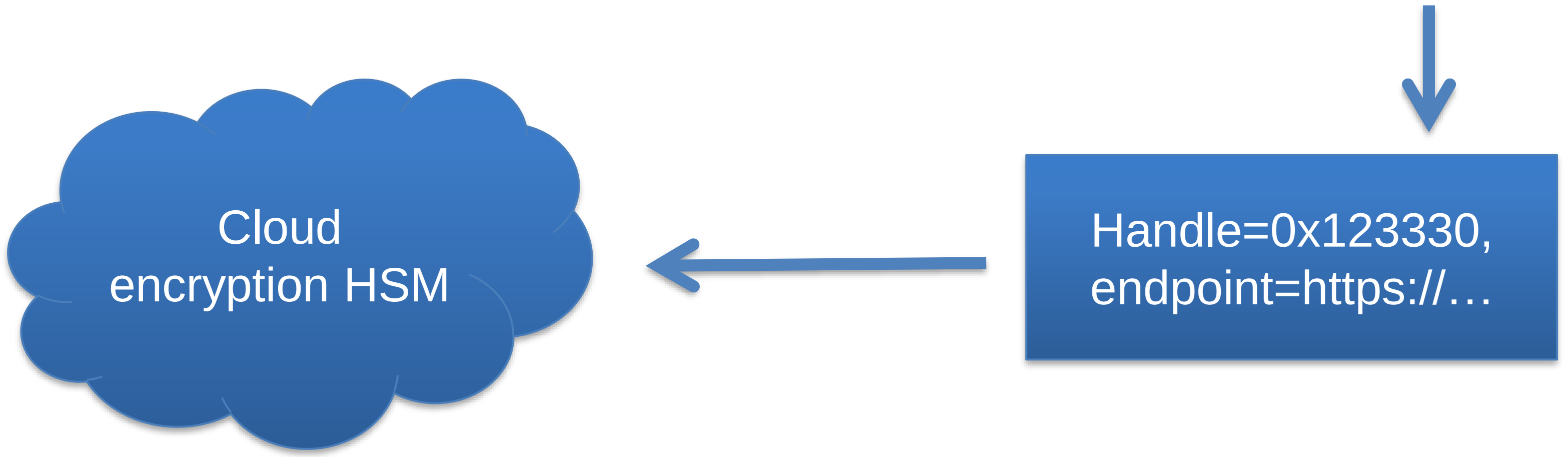
Cipher.init(Cipher.DECRYPT_MODE, key)



Cipher – Key vs KeySpec

- Why separated?

Cipher.init(Cipher.DECRYPT_MODE, key)



https://docs.oracle.com/javase/8/docs/technotes/guides/security/crypto/CryptoSpec.html#KeySpecs

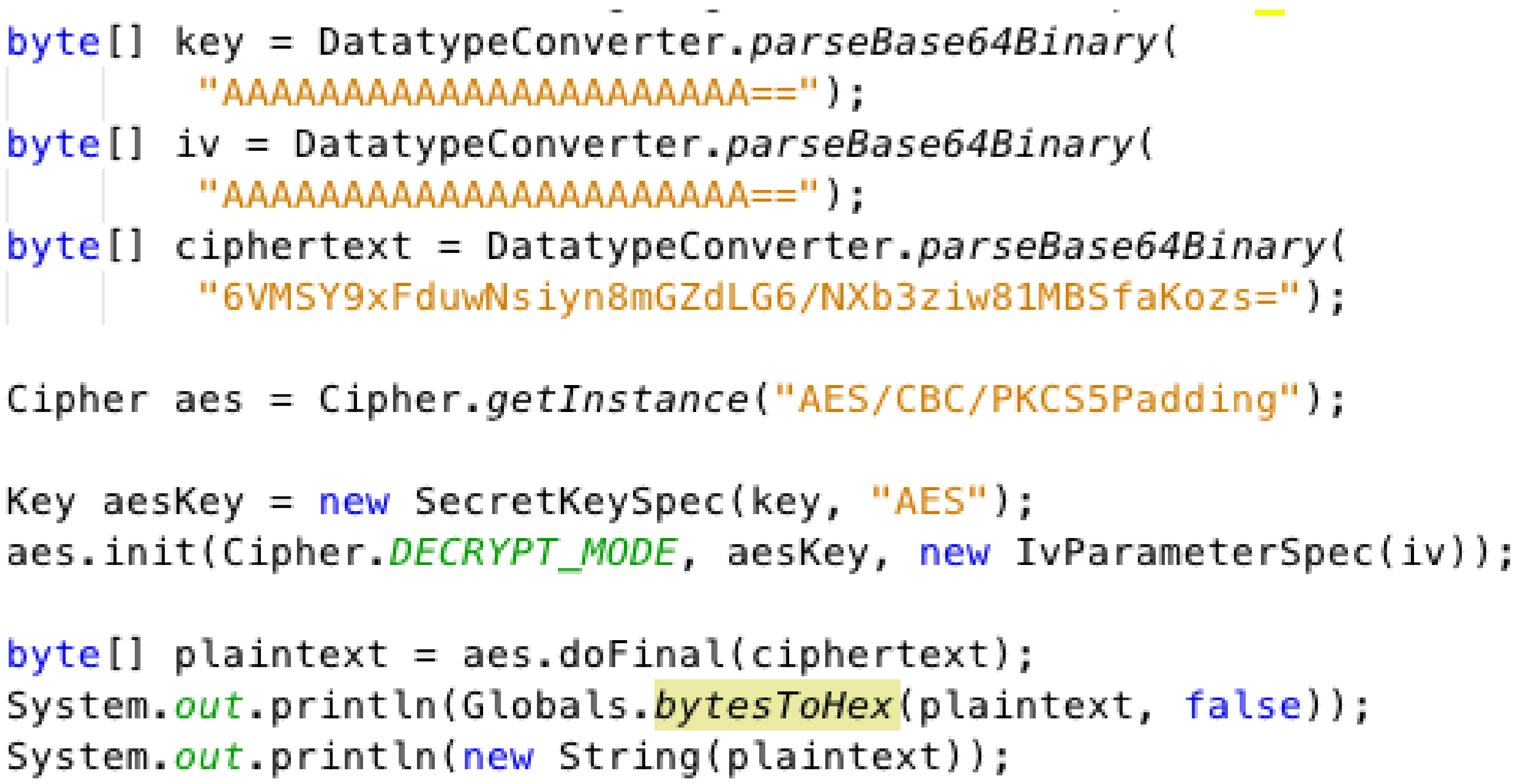
Cipher – Key materials

- String vs. char[]
  - String is immutable, cannot zero out
- Zero-out mutable byte[] after use to prevent key leakage to swap files (or Heartblead)

Cipher – Key materials

- GC deallocates but does not zero-out – key still there
- Modern GC can copy, reorder mem (heap defrag), unable to properly delete keys from memory nowadays (Java does not specify behaviour, can differ).

Cipher – Solution



```
byte[] key = DatatypeConverter.parseBase64Binary(
        "AAAAAAAAAAAAAAAAAAAAAA==");
byte[] iv = DatatypeConverter.parseBase64Binary(
        "AAAAAAAAAAAAAAAAAAAAAA==");
byte[] ciphertext = DatatypeConverter.parseBase64Binary(
        "6VMSY9xFduwNsiyn8mGZdLG6/NXb3ziw81MBSfaKozs=");

Cipher aes = Cipher.getInstance("AES/CBC/PKCS5Padding");

Key aesKey = new SecretKeySpec(key, "AES");
aes.init(Cipher.DECRYPT_MODE, aesKey, new IvParameterSpec(iv));

byte[] plaintext = aes.doFinal(ciphertext);
System.out.println(Globals.bytesToHex(plaintext, false));
System.out.println(new String(plaintext));
```

Key Factories

- KeySpec → Key
- Key → KeySpec

- KeyFactory – asymmetric keys
- SecretKeyFactory – symmetric keys

Key generators

- KeyGenerator – symmetric
  - generateSecret() → SecretKey
- KeyPairGenerator – asymmetric
  - generateKeyPair() → KeyPair

Certificate Builder

- X509V3CertificateGenerator
- Check:
  - https://web.archive.org/web/20200813000741/http://www.bouncycastle.org/wiki/display/JA1/X.509+Public+Key+Certificate+and+Certification+Request+Generation
  - https://github.com/bcgit/bc-java/wiki/BC-%22Version-2%22---The-post-BC-1.46-changes

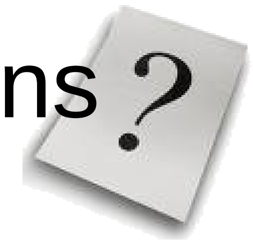
Diffie Hellman

- KeyPairGenerator
- KeyAgreement

- https://github.com/firatkucuk/diffie-hellman-helloworld

Thank you for your attention!

Questions



Assignment 10 – JavaCrypto

- This is a programming assignment. Please upload your scripts/code and the required analysis via the course webpage.
- The deadline for submission is January. 5, 2024, 23:59.
  - -3 points for each started 24h after the deadline.
- Please name the submission file as <uco_number>_hw10.zip. Put there all java project folder, and all data produced (as long as the size is reasonable).
- The code must contain comments so that it is reasonably easy to understand how to run the script for evaluating each answer.