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Safer and Faster

New JDK Security Features and Performance Improvements

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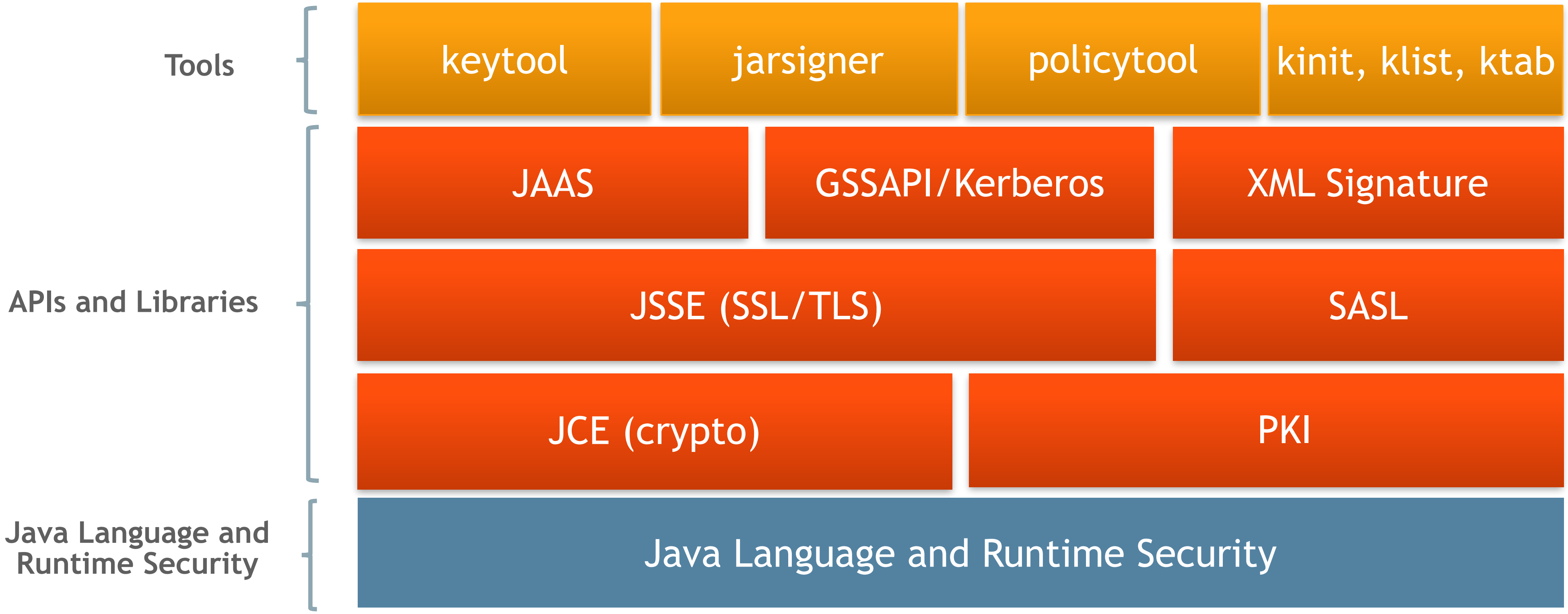
Agenda

1. Overview
2. Secure By Default Improvements
3. Performance Improvements
4. JDK 9 Security Features
5. Conclusion

Agenda

Java SE Security Components



Agenda

What is “Secure by Default”?

- Wikipedia: *“Security by default, in software, means that the default configuration settings are the most secure settings possible, which are not necessarily the most user friendly settings.”* [1]
- OWASP: *“… by default, the experience should be secure, and it should be up to the user to reduce their security – if they are allowed.”* [2]

[1] https://en.wikipedia.org/wiki/Secure_by_default
[2] https://www.owasp.org/index.php/Establish_secure_defaults

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Also …

- Wikipedia: *"In many cases, security and user friendliness are evaluated based on both risk analysis and usability tests. This leads to the discussion of what the most secure settings actually are. As a result, the precise meaning of "secure by default" remains undefined."*
- OWASP: *"It is important to understand that by no means does "Secure Defaults" mean turning off all possible network applications or sockets and services. And neither do Secure Defaults mean a 100% secure environment. But, they should ensure the least number of possible loopholes and fewer drawbacks."*

Challenges

- Compatibility
- Interoperability
- Usability
- One size does not fit all
- Phased approach
- Incorporate ability to quickly adapt to changes
  - New vulnerabilities
  - Weak or broken algorithms

Java Secure Defaults

- Initial focus: provide protection against **untrusted** code
  - Default sandbox policy
  - Restrict access to internal packages
- As scope of security APIs expanded, new defaults became necessary
  - Cryptographic algorithms were weakening or being broken
  - TLS was increasingly under attack
- Going forward, module system will introduce additional safeguards
  - Not just for code running with a Security Manager

Cryptographic Algorithm Defaults

- Direct access to crypto algorithms (via JCE) is not restricted
  - Ensures long-term compatibility
    - You can still use MD2, but you do so at your own risk
- Required algorithms are evaluated at each major release
  - Ensures every SE implementation supports industry-recommended algorithms
- Some APIs have defaults
  - `KeyStore.getDefaultType()`
    - In JDK 9, default changed from `jks` to `pkcs12`
  - `SecureRandom.getInstanceStrong()`
    - Reads `securerandom.strongAlgorithms` security property (value varies per platform)

PKI and TLS Algorithm Restrictions

- Three security properties control algorithm and key size restrictions (values shown below are for JDK 8u65)
  - **`jdk.certpath.disabledAlgorithms`**`=MD2, RSA keySize < 1024`
    - Certificate validation will fail if any of the listed algorithms or key sizes are used. Includes CRLs and OCSP responses.
  - **`jdk.tls.disabledAlgorithms`**`=SSLv3, RC4, DH keySize < 768`
    - Protocols, algorithms and key sizes listed will not be negotiated in SSL/TLS sessions
  - **`jdk.tls.legacyAlgorithms`**`=K_NULL, C_NULL, M_NULL, \`

```
    DHE_DSS_EXPORT, DHE_RSA_EXPORT, DH_anon_EXPORT, \
    DH_DSS_EXPORT, DH_RSA_EXPORT, RSA_EXPORT, \
    DH_anon, ECDH_anon, RC4_128, RC4_40, DES_CBC, DES40_CBC
```

    - Algorithms and cipher suites listed will be negotiated only if enabled and there is no other alternative

Restricted Algorithm Matrix (JDK 8, 9)

Algorithm/Protocol	*CertPath*	*TLS Legacy*	*TLS Disabled*	*Notes*
MD2	√			
MD5	√ *			*** Disabled in 9, targeted to 8u71 (Jan 2016)**
SHA-1				**Plan in development**
RSA < 1024 bits	√			
DH < 768 bits	N/A		√	
DES	N/A	√		
RC4	N/A		√	
Export CipherSuites	N/A	√		
SSLv3	N/A		√	

AlgorithmConstraints API

- Applications can also use the `AlgorithmConstraints` API to implement application-specific restrictions
- Example: extending TLS to restrict certificates with SHA-1 signatures

```
SSLParameters sslParams = new SSLParameters();
sslParams.setAlgorithmConstraints(new AlgorithmConstraints() {
    @Override
    public boolean permits(Set<CryptoPrimitive> primitives,
                           String algorithm, AlgorithmParameters params) {
        return !(primitives.contains(CryptoPrimitive.SIGNATURE) &&
            algorithm.startsWith("SHA1"));
    }
    . . .
});
```

Other TLS Secure Defaults (continued)

- SSLv3 disabled by default (January 2015: JDK 8u31)
  - Added to `jdk.tls.disabledAlgorithms` security property
- RC4 Cipher Suites disabled by default in a phased approach

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  2. Removed from default enabled cipher suites and added to `jdk.tls.legacyAlgorithms` property (July 2015: JDK 8u51)
     - Applications must explicitly enable RC4 using the `setEnabledCipherSuites` method of `SSLSocket` or `SSLEngine`
     - RC4 not used unless explicitly enabled and there are no other candidates

Other TLS Secure Defaults (continued)

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  2. Removed from default enabled cipher suites and added to `jdk.tls.legacyAlgorithms` property (July 2015: JDK 8u51)
     - Applications must explicitly enable RC4 using the `setEnabledCipherSuites` method of `SSLSocket` or `SSLEngine`
     - RC4 not used unless explicitly enabled and there are no other candidates
  3. Disabled by default (August 2015: JDK 8u60)
     - Added to `jdk.tls.disabledAlgorithms` property

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Security Tool Defaults (JDK 8, 9)

- `keytool`

Key	Key Size	Signature Algorithm
DSA	JDK 8: 1024 JDK 9: 2048	JDK 8: SHA1withDSA JDK 9: SHA256withDSA
RSA	2048	SHA256withRSA
EC	256	SHA256withECDSA

- `jarsigner`
  - digest algorithm
    - `SHA-256`
  - signature algorithm
    - same as `keytool`

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Module System Security Features (JDK 9)

- Strong encapsulation
  - A module’s packages must be exported for its public types to be accessible to other modules, e.g.:

```
module java.security.sasl {
    requires java.logging;
    exports javax.security.sasl;
}
```

  - Qualified exports allow you to export public types to one or more modules, e.g.:

```
module java.security.sasl {
    requires java.logging;
    exports javax.security.sasl;
    exports com.sun.security.sasl.util to jdk.security.jgss;
}
```

Module System Security Features (continued)

- Encapsulate most internal APIs (JEP 260)
  - With a few exceptions, all internal APIs will be inaccessible by default
    - Even if a Security Manager is not enabled
  - `IllegalAccessError` will be thrown if SecurityManager disabled
  - `AccessControlException` will be thrown if SecurityManager enabled

Module System Security Features (continued)

```
$ cat Test.java
import sun.security.x509.X509CertImpl;
public class Test {
   public static void main(String[] args) throws Exception {
       X509CertImpl cert = new X509CertImpl();
   }
}

$ javac Test.java
Test.java:1: error: package sun.security.x509 does not exist
import sun.security.x509.X509CertImpl;
…
$ javac -XaddExports:java.base/sun.security.x509=ALL-UNNAMED Test.java

$ java Test
Exception in thread "main" java.lang.IllegalAccessError: class Test (in module: Unnamed Module) cannot
access class sun.security.x509.X509CertImpl (in module: java.base), sun.security.x509 is not exported to
Unnamed Module
    at Test.main(Test.java:7)

$ java -Djava.security.manager Test
Exception in thread "main" java.security.AccessControlException: access denied
("java.lang.RuntimePermission" “accessClassInPackage.sun.security.x509”)
 …
```

Module System Security Features (continued)

- De-privilege modules that do not require `AllPermission`
  - Loaded with extension class loader
    - Applied to modules: `java.activation, java.annotations.common, java.corba, java.transaction, java.xml.bind, java.xml.ws, jdk.accessibility, jdk.crypto.ec, jdk.crypto.pkcs11, jdk.localedata, jdk.naming.dns, jdk.scripting.nashorn, jdk.xml.dom, jdk.zipfs`
  - Apply principle of least privilege, and only grant required permissions, e.g.:

```
grant codeBase “jrt:/jdk.crypto.ec” {
  permission java.lang.RuntimePermission "accessClassInPackage.sun.security.*";
  permission java.lang.RuntimePermission "loadLibrary.sunec";
  permission java.util.PropertyPermission "*", "read";
  permission java.security.SecurityPermission "putProviderProperty.SunEC";
  permission java.security.SecurityPermission "clearProviderProperties.SunEC";
  permission java.security.SecurityPermission "removeProviderProperty.SunEC";
};
```

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JCE Performance Improvements

- Since JDK 8, we have implemented major performance improvements to several cryptographic algorithms
- Most of these leverage JVM **Intrinsics**

How do Intrinsics Work?

- The HotSpot JIT compiler can compile bytecode in two ways
  - Normal compilation
  - Intrinsics, which are hand-written assembly code for specific methods that are embedded in JVM code generation logic
- For some performance critical code, normal compilation is not able to generate optimal code or use platform-specific instructions
- Before compiling a method, the JIT compiler checks for an intrinsic and if defined, uses it instead
- Intrinsics allow JCE to leverage ISA-specific hardware accelerated instructions

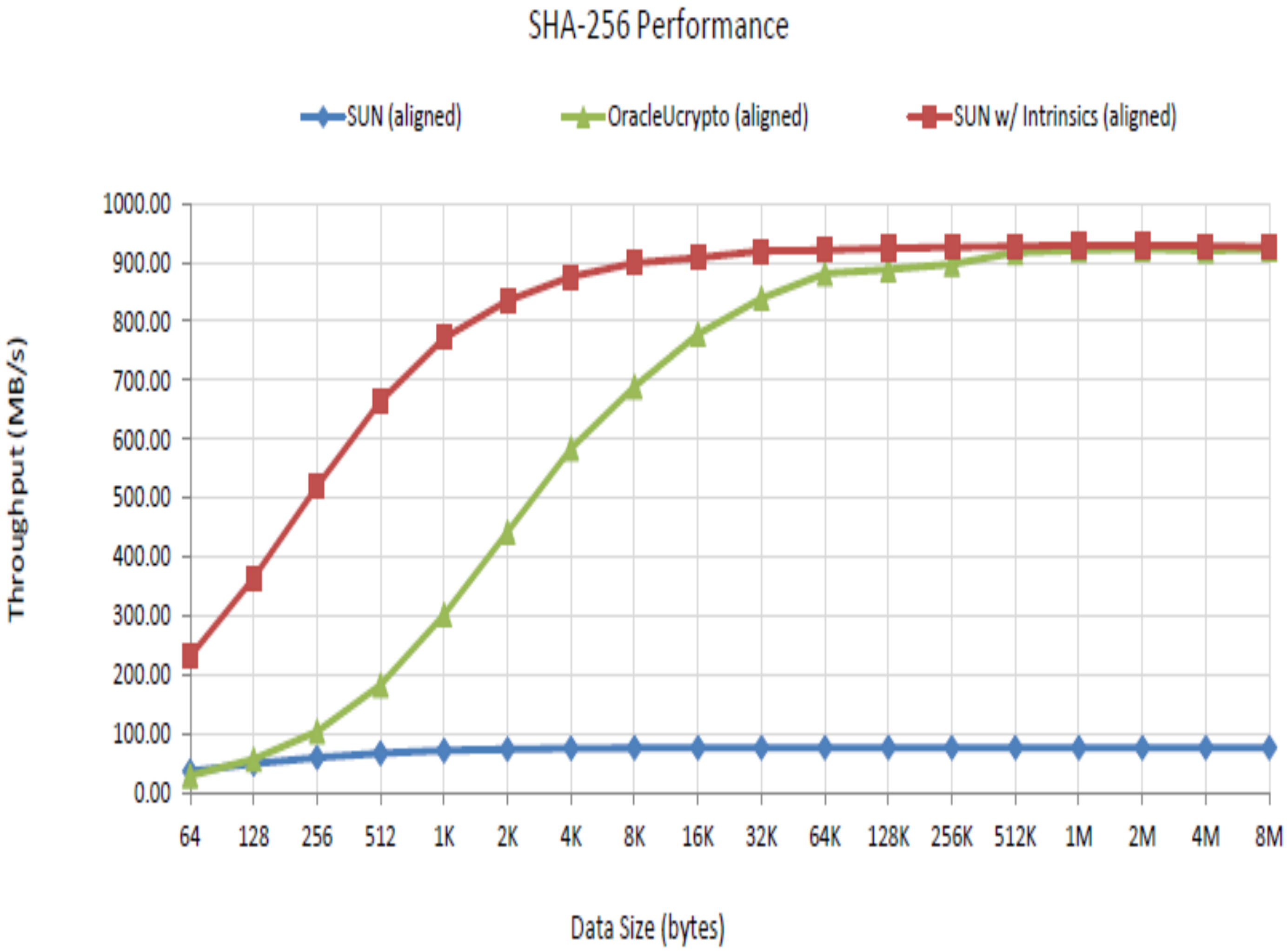
JCE Performance Improvements using Intrinsics

- JDK 8: Leverage CPU Instructions for AES Cryptography
  - http://openjdk.java.net/jeps/164
  - AES block cipher on x86 systems
- JDK 8u20: Support for AES on SPARC
  - https://bugs.openjdk.java.net/browse/JDK-8002074
  - SPARC T4 Systems and beyond

JCE Performance Improvements using Intrinsics (cont)

- JDK 8u40: Leverage CPU Instructions to Improve SHA
  - http://openjdk.java.net/jeps/207
  - SHA1 and SHA2 message digests on SPARC systems
- JDK 9: Leverage CPU Instructions for GHASH and RSA
  - http://openjdk.java.net/jeps/246
  - GHASH (used in AES/GCM mode) on x86/SPARC systems and RSA on x86_64 systems

SHA-256 Performance on SPARC



- SHA-256: up to **7.8x** faster (in throughput) than OracleUcrypto
  - More gain at smaller data sizes
- SHA-1 (not shown): up to **7.7x** faster than OracleUcrypto
- SecureRandom
  - SHA1PRNG: 48% improvement

HTTPS Benchmark Performance on SPARC

Benchmark: HTTP Servlet
Response Size = 1K
Cipher Suite: TLS_ECDHE_RSA_WITH_AES_128_CBC_SHA
Number of Users: 90

Providers	Throughput (ops/sec)	%CPU	Ops/sec/ %CPU	Gain (factor)
Java w/o Intrinsics	76185	91	837	1
Java+Ucrypto	88816	82	1083	1.29
Java+AES Intrinsics	97791	76	1287	1.54
Java+AES+SHA Intrinsics	110033	66	1667	1.99

- AES and SHA Intrinsics significantly improve performance of HTTPS
- **99%** faster in throughput over pure Java

RSA Comparison with Specjvm2008 crypto.rsa on Solaris

- SPARC T7-1@4.13GHz (Tahoe)
- OS version: Solaris 12.0 b69 (March 2015)
- JDK 1.9.0 b74
- Single-threaded runs

Crypto.rsa	RSA->Ucrypto	RSA->intrinsic	RSA->pure java
Throughput (Ops/min)	649.51	N/A	57.48

- Intel X5-2 Xeon E5-2690 v3 @2.60GHz (Haswell)
- OS version: Solaris 11.3 b15 (Feb 2015)
- JDK 1.9.0 b74
- Single-threaded runs

Crypto.rsa	RSA->Ucrypto	RSA->intrinsic	RSA->pure java
Throughput (Ops/min)	351.92	362.79	150.79

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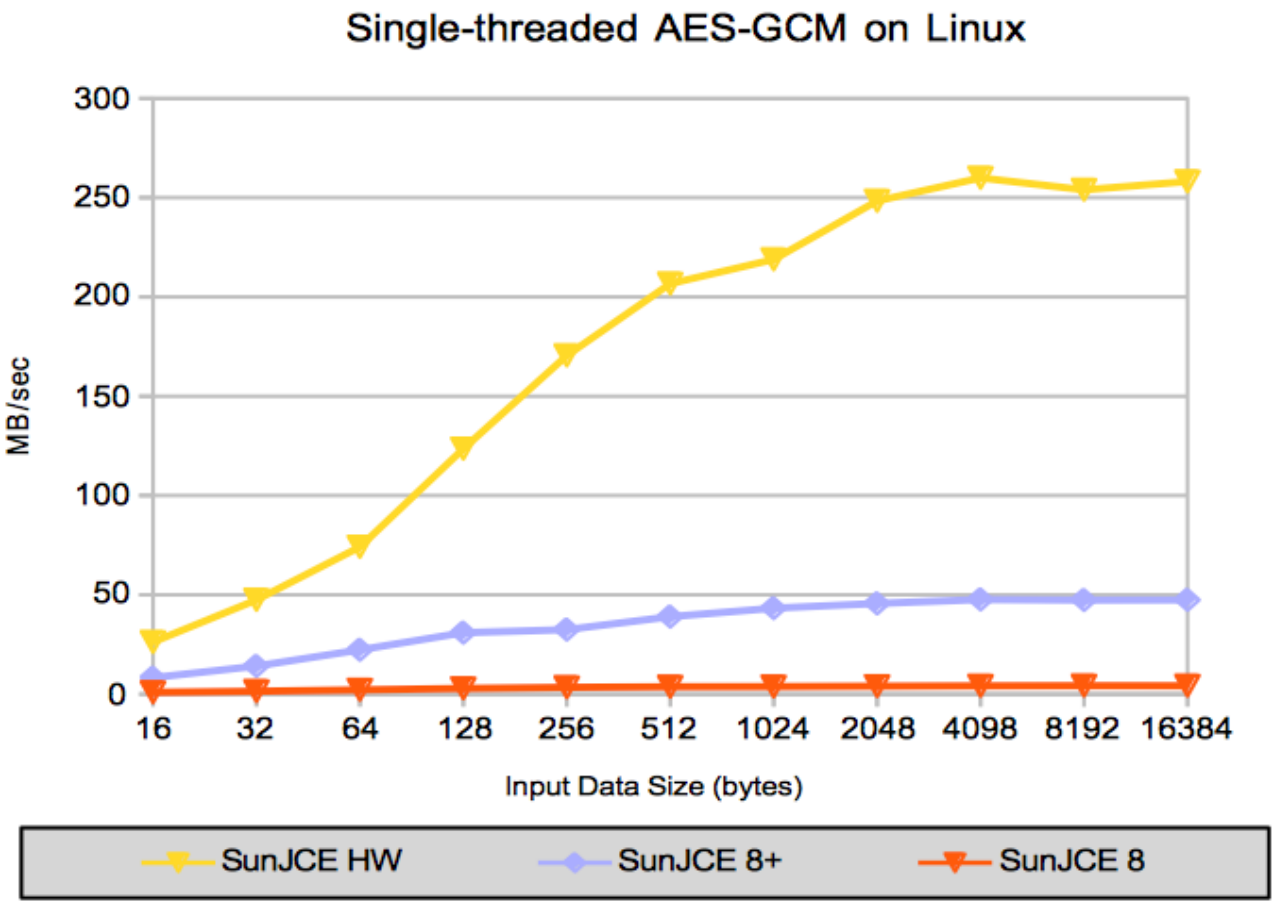
AES/GCM Performance on x86



- JDK 9: up to a **62x** performance gain over the JDK 8 GA implementation
  - up to **5.45x** over 8u60 implementation
- 8u60 performance improved due to:
  - https://bugs.openjdk.java.net/browse/JDK-8069072

Improve Secure Application Performance (JDK 9)

- Improve performance of applications run with a Security Manager enabled (JEP 232)
- Optimizations implemented:
  - Reduced number of synchronized blocks
  - Used concurrent collections to cache Permissions, ProtectionDomains, etc
  - Improved speed of `SecurityManager.checkPackageAccess()`
  - Eliminated name service lookup from `CodeSource.hashCode()`
- Increased speed and throughput of permission checks
- Did not focus on stack walking or `AccessController.doPrivileged()`

SPECjEnterprise Benchmark Results

Method	Improvement (Inclusive CPU Time)
`AccessController.checkPermission()`	22.7%
`AccessControlContext.checkPermission()`	64%
`ProtectionDomain.implies()`	65.4%
`Permissions.implies()`	35.9%
`SecurityManager.checkPackageAccess()`	29.6%

Overall overhead of Security Manager (in response time): 4.68%

Duke wins … again!

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JDK 9 Security Features

http://openjdk.java.net/jeps/0

- JEP 219: Datagram Transport Layer Security (DTLS)
- JEP 229: Create PKCS12 Keystores by Default
- JEP 232: Improve Secure Application Performance
- JEP 244: TLS Application-Layer Protocol Negotiation Extension
- JEP 246: Leverage CPU Instructions for GHASH and RSA
- JEP 249: OCSP Stapling for TLS
- JEP 273: DRBG-Based SecureRandom Implementations

JEP 229: Create PKCS12 Keystores by Default

- Transition the default keystore type from JKS to PKCS12
- Improved security and flexibility
  - PKCS12 supports stronger cryptographic algorithms than JKS
  - PKCS12 supports secret keys and attributes
- Compatibility is maintained
  - A JKS keystore can read a PKCS12 keystore and vice-versa
- `KeyStore.getDefaultType()` will now return `“pkcs12”`
- New `KeyStore.getInstance(File, …)` methods for automatically determining type of keystore

Create PKCS12 Keystores by Default (Example)

```
// Create default keystore type
KeyStore ks = KeyStore.getInstance(KeyStore.getDefaultType());

// Prints “pkcs12”
System.out.println(ks.getType());

// Load keystore
try (FileInputStream fis = new FileInputStream("keystore.p12")) {
    ks.load(fis, "password".toCharArray());
}

// Or preferably, use new file probing API to automatically determine type
ks = KeyStore.getInstance(new File(“keystore.p12"), “password”.toCharArray());
```

JEP 246: Leverage CPU Instructions for GHASH/RSA

Improved Provider Configuration

- The existing provider configuration security properties (in the `java.security` file) have limitations
  - Insufficient for providers that offer large performance gains for some, but not all algorithms
    - E.g.: on Solaris, the SunJCE provider in JDK 9 offers better performance for AES/GCM but the Ucrypto provider performs better for other algorithms
- A new `jdk.security.provider.preferred` property will allow specific providers to be chosen before others, e.g.:

```
jdk.security.provider.preferred=AES/GCM:SunJCE,\
                                MessageDigest.SHA-256:SUN
```

JEP 273: DRBG-Based SecureRandom Implementations

- Implement the three Deterministic Random Bit Generator (DRBG) mechanisms described in NIST 800-90Ar1
  - Use modern algorithms as strong as SHA-512 and AES-256
  - Each can be configured to better match user requirements
  - Support for mechanisms becoming very important in some environments
- Add new methods to `SecureRandom` for DRBG operations
- Add new APIs for specifying Entropy Input as described in NIST SP 800-90B and 800-90C

DRBG-Based SecureRandom Implementations (Example)

NOTE: API is still under discussion

```
// Create SecureRandom for “HashDRBG” mechanism
SecureRandom sr = SecureRandom.getInstance(“HashDRBG”);

// Optionally, configure DRBG
// (not all code shown)
DrbgSpec spec =
    new DrbgSpec(entropyInput, “SHA-256”, 256, true, false, nonce, personal);
sr.configure(spec);

// Generate random bytes
sr.nextBytes(random);
```

JEP 219: Datagram Transport Layer Security (DTLS)

- Extend the JSSE API and implementation to support DTLS (RFCs 4347 and 6347)
- TLS must run over a reliable transport channel such as TCP
- DTLS allows applications to use TLS over an unreliable transport channel such as UDP
  - An increasing number of application protocols use UDP, e.g.: SIP, CoAP, SRTP
- Applications use the `SSLEngine` programming model to use DTLS

JEP 249: OCSP Stapling for TLS

- Implement the TLS Certificate Status Request Extensions (RFCs 6066 and 6961)
- Client-side OCSP checking incurs significant performance overhead
- With OCSP Stapling, the server is responsible for obtaining and sending the OCSPResponse to the client. This has several benefits:
  - Performance: responses can be cached and sent to all clients
  - Security
    - Allows captive portals to check revocation status
    - Avoids client-side privacy leaks

OCSP Stapling for TLS (Example)

On the Client

```
// By default, OCSP Stapling is enabled if revocation checking is enabled.
// To disable, set the system property jdk.tls.client.enableStatusRequestExtension
// to false.

SSLContext context = SSLContext.getInstance(“TLS”);
TrustManagerFactory fac = TrustManagerFactory.getInstance(“PKIX”);

// To enable revocation checking, either:
// 1. Set revocation property to true
System.setProperty(“com.sun.net.ssl.checkRevocation”, “true”);
fac.init(keyStore);

// Or, 2. use PKIXBuilderParameters and revocation is enabled by default
PKIXBuilderParameters params =
    new PKIXBuilderParameters(anchors, new X509CertSelector());
ManagerFactoryParameters trustParams = new CertPathTrustManagerParameters(params);
fac.init(trustParams);

context.init(null, fac.getTrustManagers(), null);
```

OCSP Stapling for TLS (Example)

On the Server

```
// Enable OCSP Stapling (off by default)
System.setProperty("jdk.tls.server.enableStatusRequestExtension", "true");

// Yes, that's really it!

// Optionally, several other system properties can be set for advanced usages.

// cache lifetime, in seconds (default: 3600)
System.setProperty("jdk.tls.stapling.cacheLifetime", 7200);

// cache size, number of entries (default: 256)
System.setProperty("jdk.tls.stapling.cacheSize", 128);

// and a few more …
```

JEP 244: TLS Application-Layer Negotiation Extension (ALPN)

- Add API support for the ALPN TLS Extension (RFC 7301), which provides the means to negotiate an application protocol used over a TLS connection
- An important consumer of this feature is the HTTP/2 client (JEP 110/ RFC 7540)

TLS Application-Layer Negotiation Extension (Example)

On the Client

```
SSLParameters params = sslSocket.getSSLParameters();

// Set application protocols to “h2” (HTTP/2) and “http/1.1”
params.setApplicationProtocols(new String[]{"h2", “http/1.1”});

// Optionally, set other parameters, cipher suites, etc

sslSocket.setSSLParameters(params);

sslSocket.startHandshake();

if (sslSocket.getApplicationProtocol().equals(“h2”)) {
    . . .
}
```

Agenda

Conclusion

- Security is **important**
- We continue to make Java more secure and faster and incorporate new security features
- You can help us!
  - Let us know what you think is important
  - Participate: http://openjdk.java.net/groups/security/
  - Contribute: http://openjdk.java.net/contribute

Acknowledgements

- Solaris Performance Application Engineering Team for performance charts
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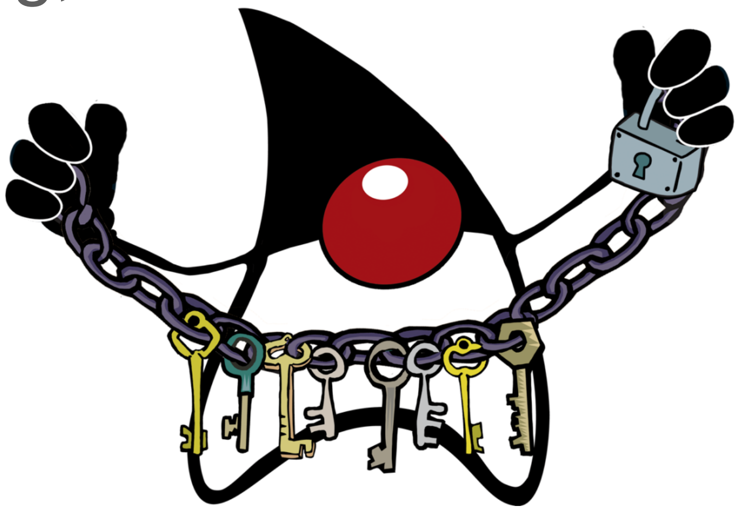

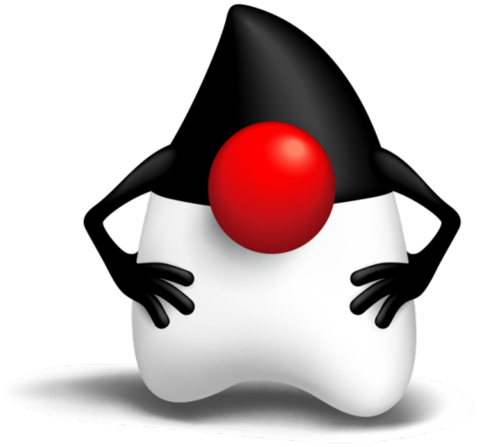

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