Elasticsearch

Securing a search engine while maintaining usability

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Elasticsearch in 10 seconds

- Search Engine (FTS, Analytics, Geo), real-time
- Distributed, scalable, highly available, resilient
- Interface: HTTP & JSON
- Centrepiece of the Elastic Stack (Kibana, Logstash, Beats, APM, ML, Swiftype)
- Uneducated guess: Tens of thousands of clusters worldwide, hundreds of thousands of instances

Agenda

- Security: Feature or non-functional requirement?
- Security Manager
- Production Mode vs. Development Mode
- Plugins
- Scripting language: Painless

Security

Feature or non-functional requirement?

Security as a non-functional requirement

- Software has to be secure! O RLY?

- Defensive programming
- Do not persist specific data (PCI DSS)
- Not exploitable (pro tip: not gonna happen)
- No unintended resource access (directory traversal)
- Least privilege principle
- Reduced impact surface (DoS)

Security as a feature

- Commercial extension for the Elastic Stack
- Authentication
- Authorization (LDAP, users, PKI)
- TLS transport encryption
- Audit logging
- SSO/SAML/Kerberos

Security or resiliency?

- Integrity checks
- Preventing OOMEs
- Prevent deep pagination
- Do not expose credentials in cluster state/REST APISs
- Stop writing data before running out of disk space
- Unable to call `System.exit`

> „[T]HERE ARE **KNOWN KNOWNS**; THERE ARE THINGS WE KNOW WE KNOW. WE ALSO KNOW THERE ARE **KNOWN UNKNOWNS**; THAT IS TO SAY WE KNOW THERE ARE SOME THINGS WE DO NOT KNOW. BUT THERE ARE ALSO **UNKNOWN UNKNOWNS** – THERE ARE THINGS WE DO NOT KNOW WE DON'T KNOW.“

Donald Rumsfeld, ~~former secretary of defense~~, IT Security Expert

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Security Manager

Have you ever called `System.setSecurityManager()`?

Introduction

- Sandbox your java application
- Prevent certain calls by your application
- Policy file grants permissions
  - FilePermission (read, write)
  - SocketPermission (connect, listen, accept)
  - URLPermission, PropertyPermission, ...

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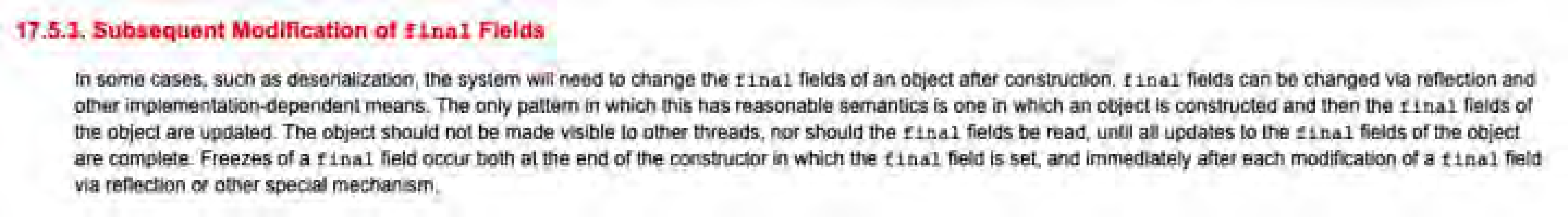
DEMO

OHAI JLS



17.5.3. Subsequent Modification of `final` Fields

In some cases, such as deserialization, the system will need to change the `final` fields of an object after construction. `final` fields can be changed via reflection and other implementation-dependent means. The only pattern in which this has reasonable semantics is one in which an object is constructed and then the `final` fields of the object are updated. The object should not be made visible to other threads, nor should the `final` fields be read, until all updates to the `final` fields of the object are complete. Freezes of a `final` field occur both at the end of the constructor in which the `final` field is set, and immediately after each modification of a `final` field via reflection or other special mechanism.

https://docs.oracle.com/javase/specs/jls/se11/html/jls-17.html#jls-17.5.3

Drawbacks

- Hardcoded policies before startup
- DNS lookups are cached forever unless changed in JVM
- Forces you to think about dependencies!
- Many libraries are not even tested with the security manager, unknown code paths may be executed
- No OOM protection! No stack overflow protection!
- Granularity
- No protection against java agents

Production mode vs Development mode

Annoying you now instead of devastating you later

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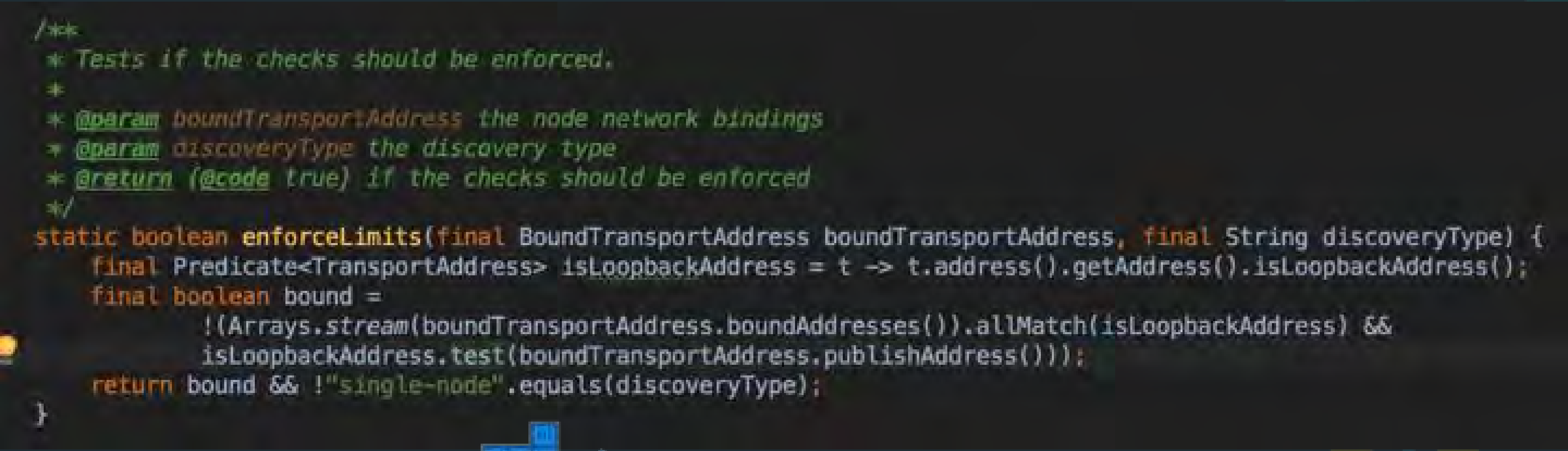
Is your dev setup equivalent to production?

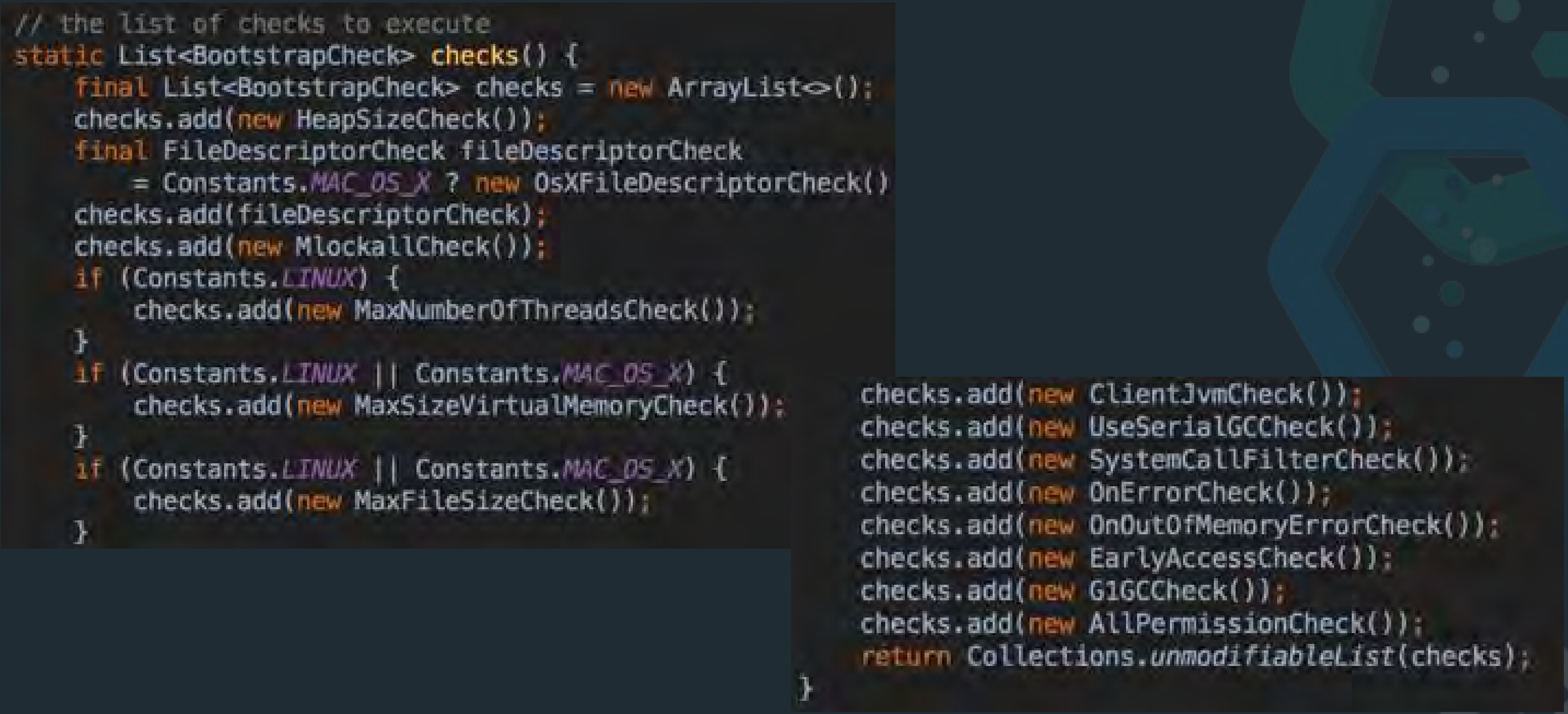
- Development environments are rarely setup like production ones
- How to ensure certain preconditions in production but not for development?
- What is a good indicator?

Mode check



```java
/**
 * Tests if the checks should be enforced.
 *
 * @param boundTransportAddress the node network bindings
 * @param discoveryType the discovery type
 * @return {@code true} if the checks should be enforced
 */
static boolean enforceLimits(final BoundTransportAddress boundTransportAddress, final String discoveryType) {
    final Predicate<TransportAddress> isLoopbackAddress = t -> t.address().getAddress().isLoopbackAddress();
    final boolean bound =
            !(Arrays.stream(boundTransportAddress.boundAddresses()).allMatch(isLoopbackAddress) &&
            isLoopbackAddress.test(boundTransportAddress.publishAddress()));
    return bound && !"single-node".equals(discoveryType);
}
```

Bootstrap checks



```
// the list of checks to execute
static List<BootstrapCheck> checks() {
    final List<BootstrapCheck> checks = new ArrayList<>();
    checks.add(new HeapSizeCheck());
    final FileDescriptorCheck fileDescriptorCheck
        = Constants.MAC_OS_X ? new OsXFileDescriptorCheck()
    checks.add(fileDescriptorCheck);
    checks.add(new MlockallCheck());
    if (Constants.LINUX) {
        checks.add(new MaxNumberOfThreadsCheck());
    }
    if (Constants.LINUX || Constants.MAC_OS_X) {
        checks.add(new MaxSizeVirtualMemoryCheck());
    }
    if (Constants.LINUX || Constants.MAC_OS_X) {
        checks.add(new MaxFileSizeCheck());
    }
```

```
    checks.add(new ClientJvmCheck());
    checks.add(new UseSerialGCCheck());
    checks.add(new SystemCallFilterCheck());
    checks.add(new OnErrorCheck());
    checks.add(new OnOutOfMemoryErrorCheck());
    checks.add(new EarlyAccessCheck());
    checks.add(new G1GCCheck());
    checks.add(new AllPermissionCheck());
    return Collections.unmodifiableList(checks);
}
```

Reducing impact

Bad things have less bad results

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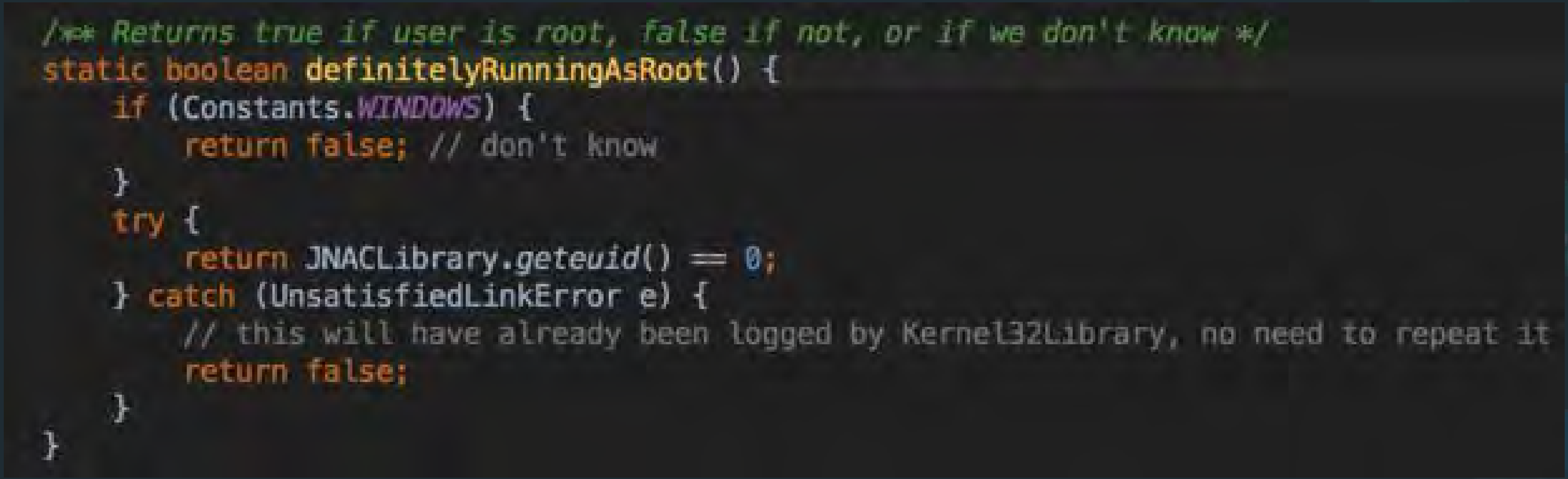
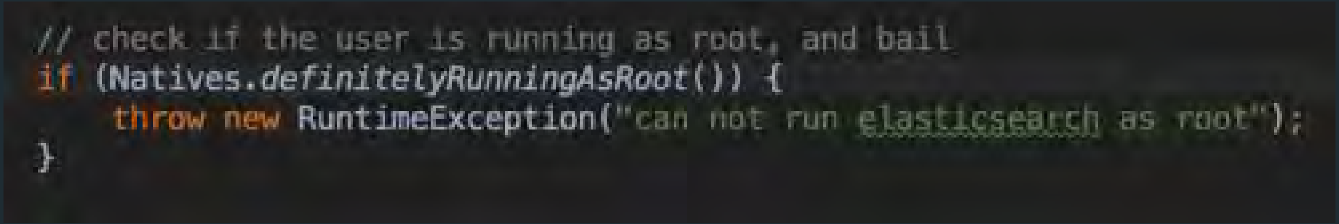
Reducing impact

- Least privilege principle
- Do not run as root
- No chance of forking a process
- Do not expose sensitive settings in API calls
- Security Manager

Do not run as root



```
/** Returns true if user is root, false if not, or if we don't know */
static boolean definitelyRunningAsRoot() {
    if (Constants.WINDOWS) {
        return false; // don't know
    }
    try {
        return JNACLibrary.geteuid() == 0;
    } catch (UnsatisfiedLinkError e) {
        // this will have already been logged by Kernel32Library, no need to repeat it
        return false;
    }
}
```



```
// check if the user is running as root, and bail
if (Natives.definitelyRunningAsRoot()) {
    throw new RuntimeException("can not run elasticsearch as root");
}
```

Seccomp - prevent process forks

- Security manager could fail
- Elasticsearch should still not be able to fork processes
- One way transition to tell the operating system to deny `execve`, `fork`, `vfork`, `execveat` system calls
- Works on Linux, Windows, Solaris, BSD, osx

Security Manager in Elasticsearch

- Elasticsearch needs to read its configuration file first to find out about the file paths
- Native code needs to be executed first
- Only then we can start the security manager
- Solution: Start with empty security manager, bootstrap, apply secure security manager

Security Manager in Elasticsearch

- Special security manager is used
- Does not set `exitVM` permissions, only a few special classes are allowed to call
- Thread & ThreadGroup security is enforced
- Also **`SpecialPermission`** was added, a special marker permission to prevent elevation by scripts

Security Manager in Elasticsearch

- `ESPolicy` allows for loading from files plus dynamic configuration (from the ES configuration file)
- Bootstrap check for `java.security.AllPermission`
- Quiz question: Do you know which version we introduced the security manager? Did Elasticsearch become harder to use for you?

Plugins

... remaining secure

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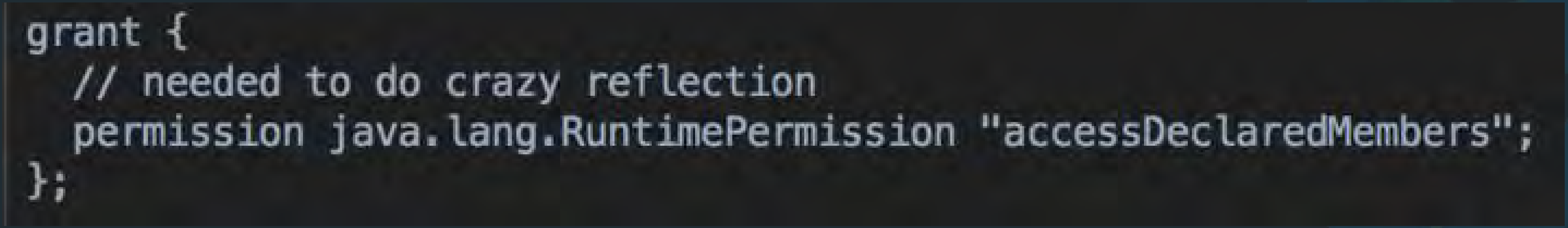
Plugins in 60 seconds

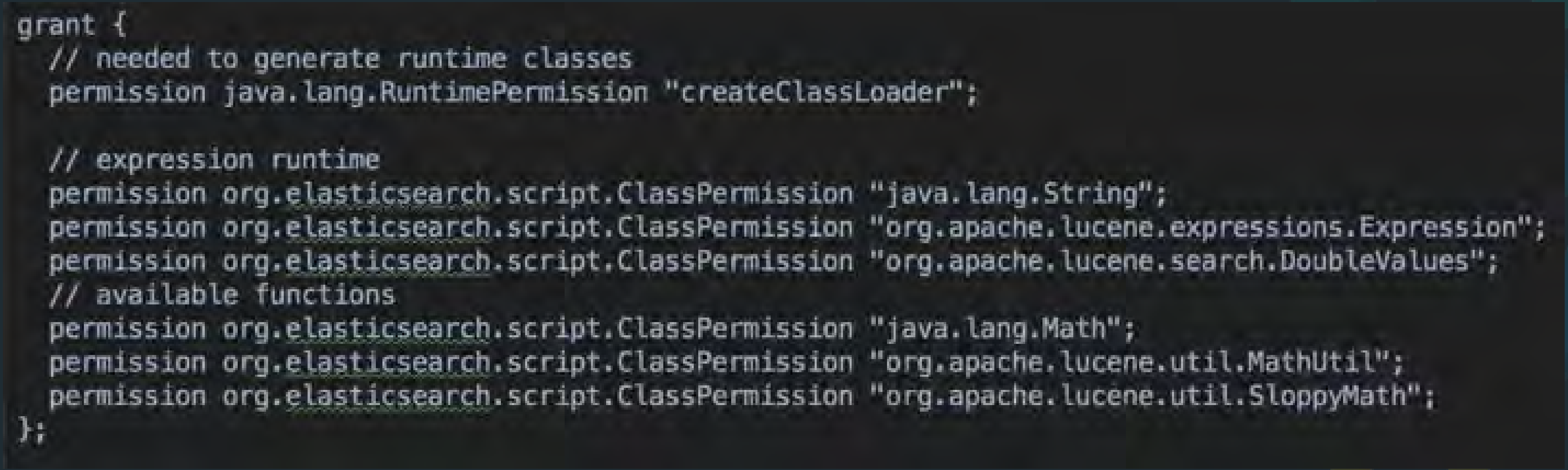
- plugins are just zip files
- each plugin can have its own jars/dependencies
- each plugin is loaded with its own classloader
- each plugin can have its own security permissions
- ES core loads a bunch of code as modules (plugins that ship with Elasticsearch)

Sample permissions



```
grant {
  // needed to do crazy reflection
  permission java.lang.RuntimePermission "accessDeclaredMembers";
};
```

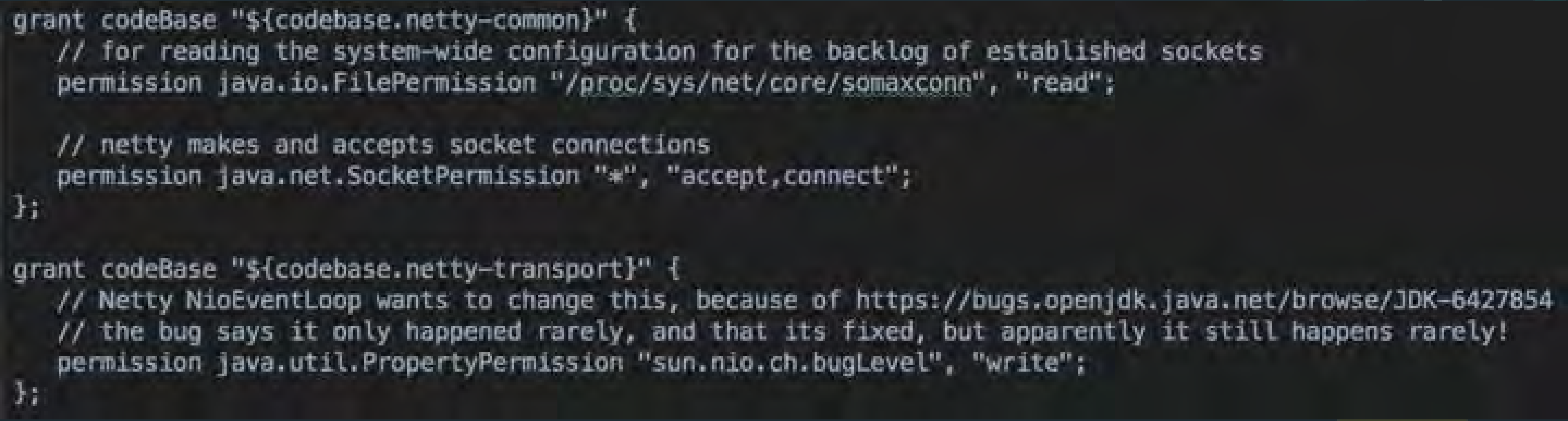
Sample permissions



```
grant {
  // needed to generate runtime classes
  permission java.lang.RuntimePermission "createClassLoader";

  // expression runtime
  permission org.elasticsearch.script.ClassPermission "java.lang.String";
  permission org.elasticsearch.script.ClassPermission "org.apache.lucene.expressions.Expression";
  permission org.elasticsearch.script.ClassPermission "org.apache.lucene.search.DoubleValues";
  // available functions
  permission org.elasticsearch.script.ClassPermission "java.lang.Math";
  permission org.elasticsearch.script.ClassPermission "org.apache.lucene.util.MathUtil";
  permission org.elasticsearch.script.ClassPermission "org.apache.lucene.util.SloppyMath";
};
```

Sample permissions



```
grant codeBase "${codebase.netty-common}" {
   // for reading the system-wide configuration for the backlog of established sockets
   permission java.io.FilePermission "/proc/sys/net/core/somaxconn", "read";

   // netty makes and accepts socket connections
   permission java.net.SocketPermission "*", "accept,connect";
};

grant codeBase "${codebase.netty-transport}" {
   // Netty NioEventLoop wants to change this, because of https://bugs.openjdk.java.net/browse/JDK-6427854
   // the bug says it only happened rarely, and that its fixed, but apparently it still happens rarely!
   permission java.util.PropertyPermission "sun.nio.ch.bugLevel", "write";
};
```

Introducing Painless

A scripting language for Elasticsearch

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Scripting: Why and how?

- Expression evaluation without needing to write java extensions for Elasticsearch

- Node ingest script processor
- Search queries (dynamic requests & fields)
- Aggregations (dynamic buckets)
- Templating (Mustache)

Scripting in Elasticsearch

- MVEL
- Groovy
- Expressions
- Painless

Painless - a secure scripting language

- Hard to take an existing programming language and make it secure, but remain fast
- Sandboxing
- Whitelisting over blacklisting, per method
- Opt-in to regular expressions
- Prevent endless loops
- Detect self references to prevent stack overflows

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DEMO

Summary

Security is hard - let's go shopping!

Summary

- Not using the Security Manager - what's your excuse?
- Scripting is important, is your implementation secure?
- Use operating system features!
- If you allow for plugins, remain secure!
- If you remove features, have alternatives!

Thanks for listening!

Questions?

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Resources

- https://github.com/elastic/elasticsearch/
- https://www.elastic.co/blog/bootstrap_checks_annoying_instead_of_devastating
- https://www.elastic.co/blog/scripting
- https://www.elastic.co/blog/scripting-security
- https://docs.oracle.com/javase/9/security/toc.htm
- https://docs.oracle.com/javase/9/security/permissions-java-development-kit.htm

Bonus

deep pagination vs search_after

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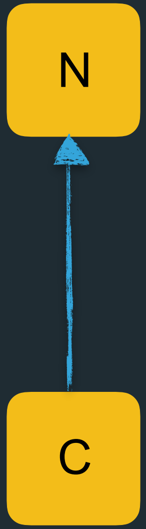
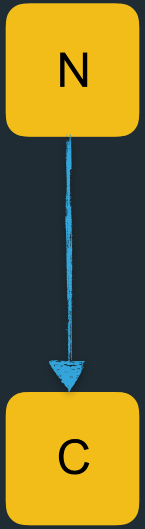
Pagination: Request



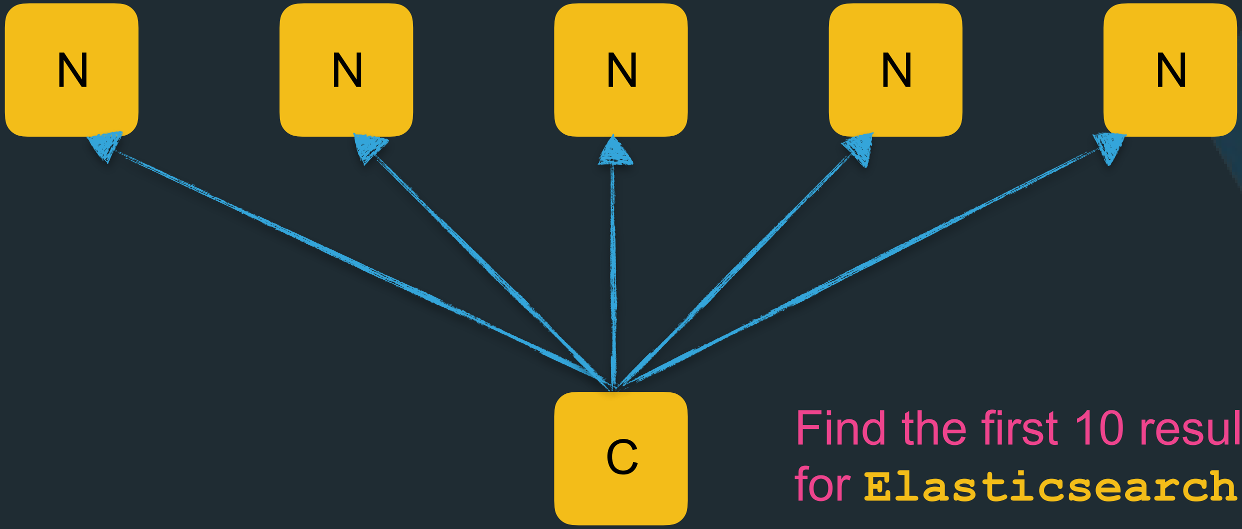
Find the first 10 results
for **`Elasticsearch`**

Pagination: Request



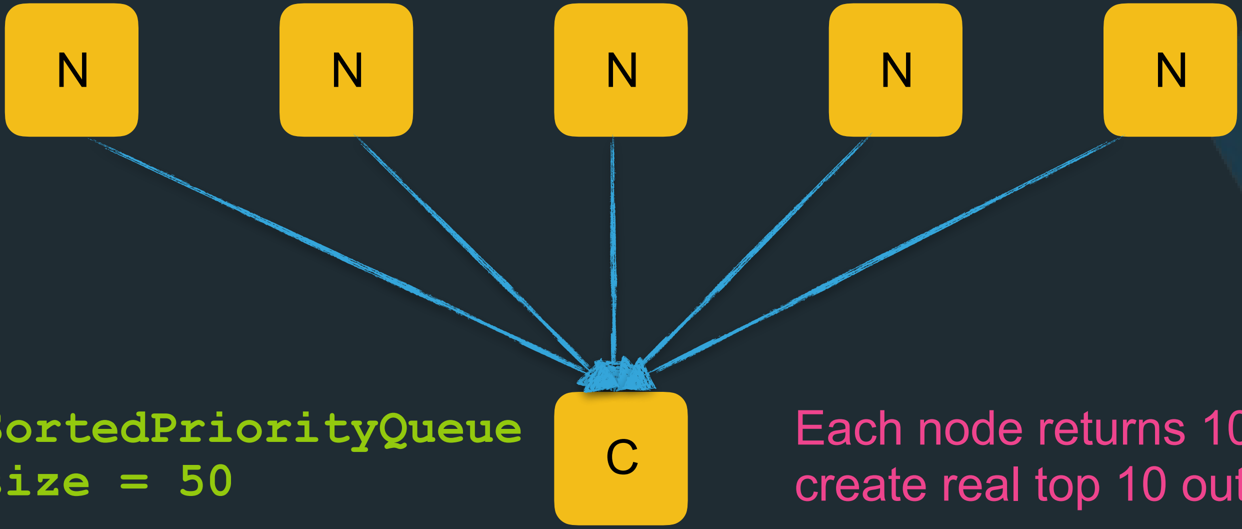
Find the first 10 results for **`Elasticsearch`**

Pagination: Request



Find the first 10 results for `Elasticsearch`

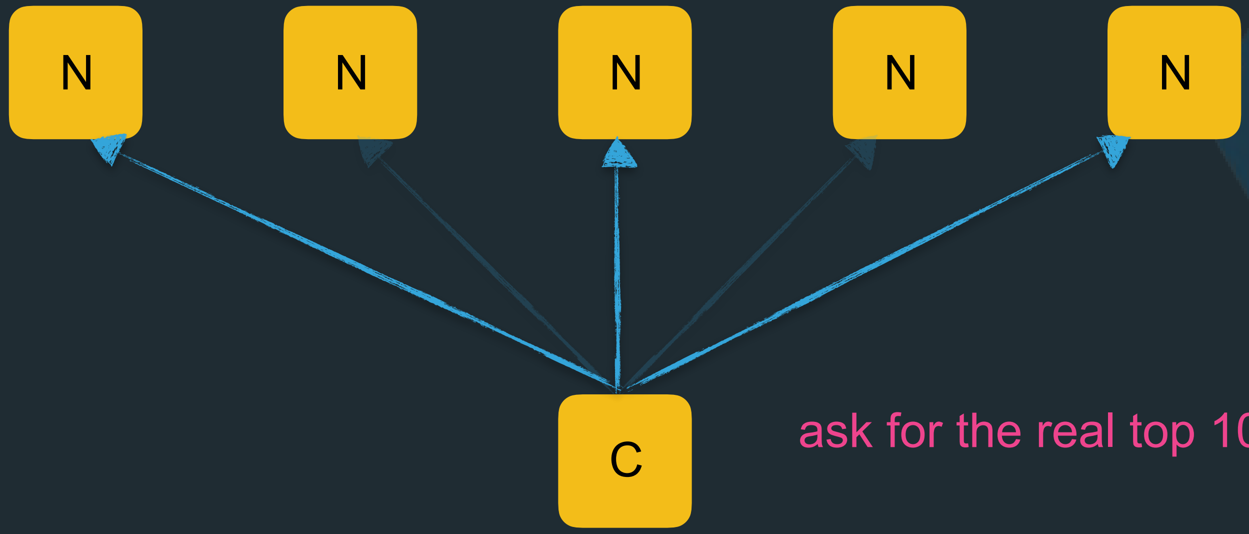
Pagination: Query Phase



`SortedPriorityQueue`
`size = 50`

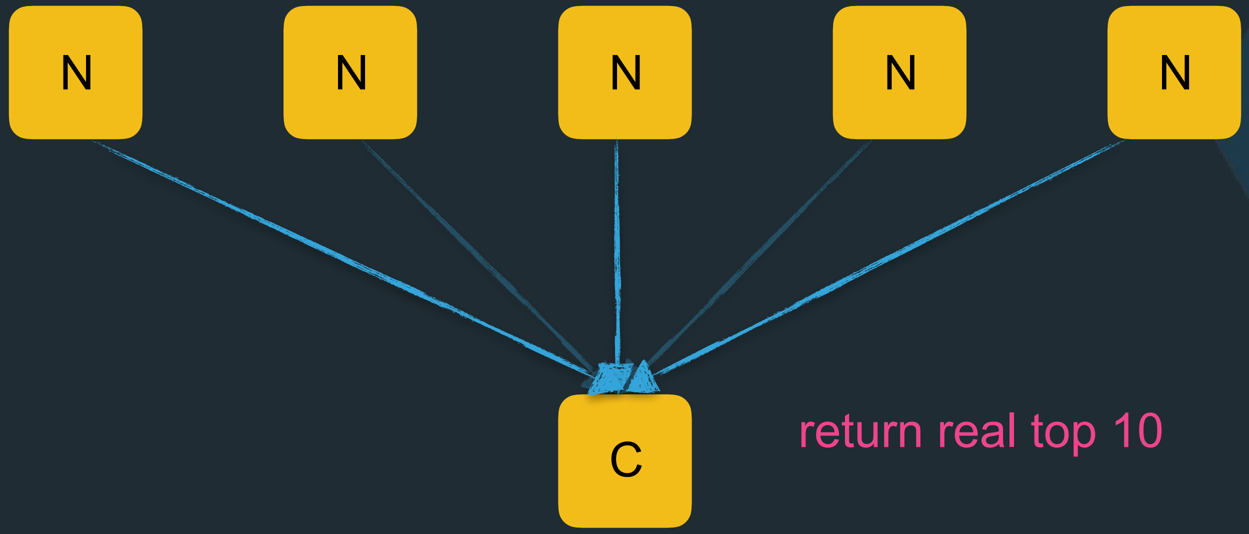
Each node returns 10 results, create real top 10 out of 50

Pagination: Fetch phase



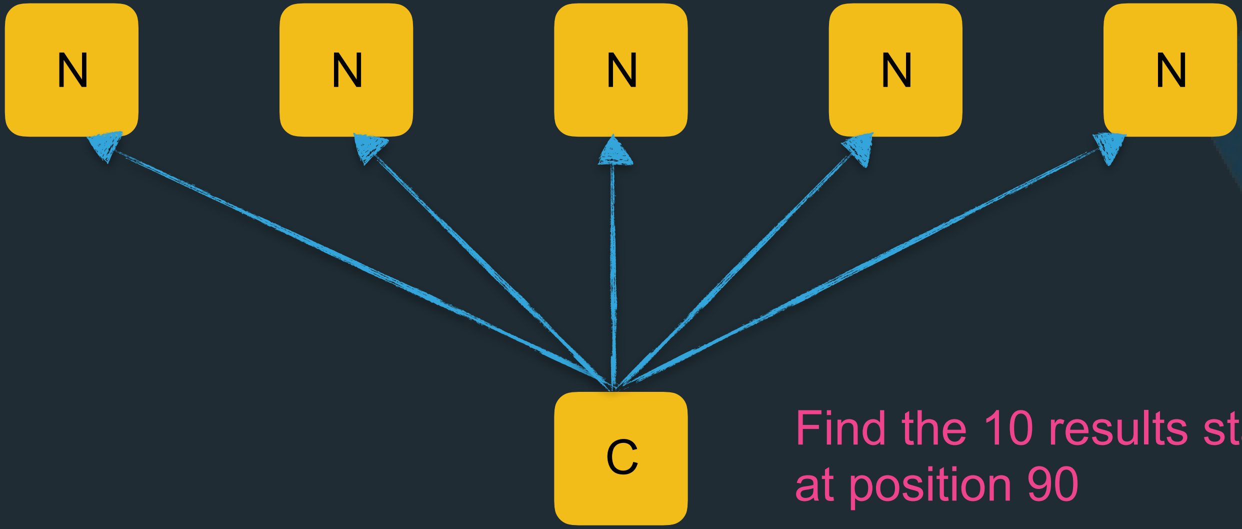
ask for the real top 10

Pagination: Query Phase



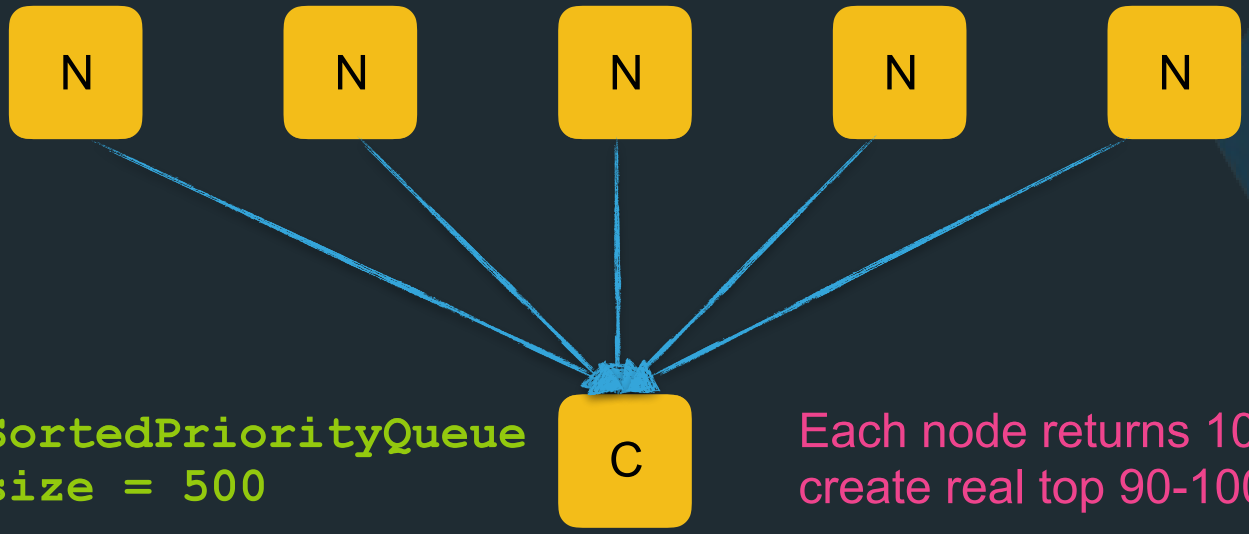
return real top 10

Pagination: Query



Find the 10 results starting at position 90

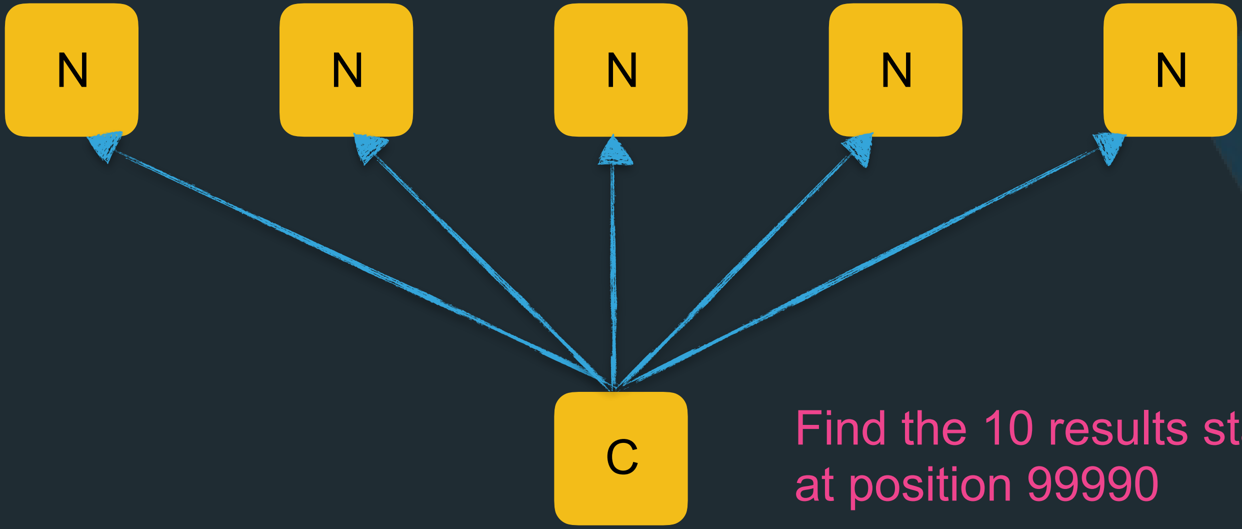
Pagination: Query Phase



SortedPriorityQueue
size = 500

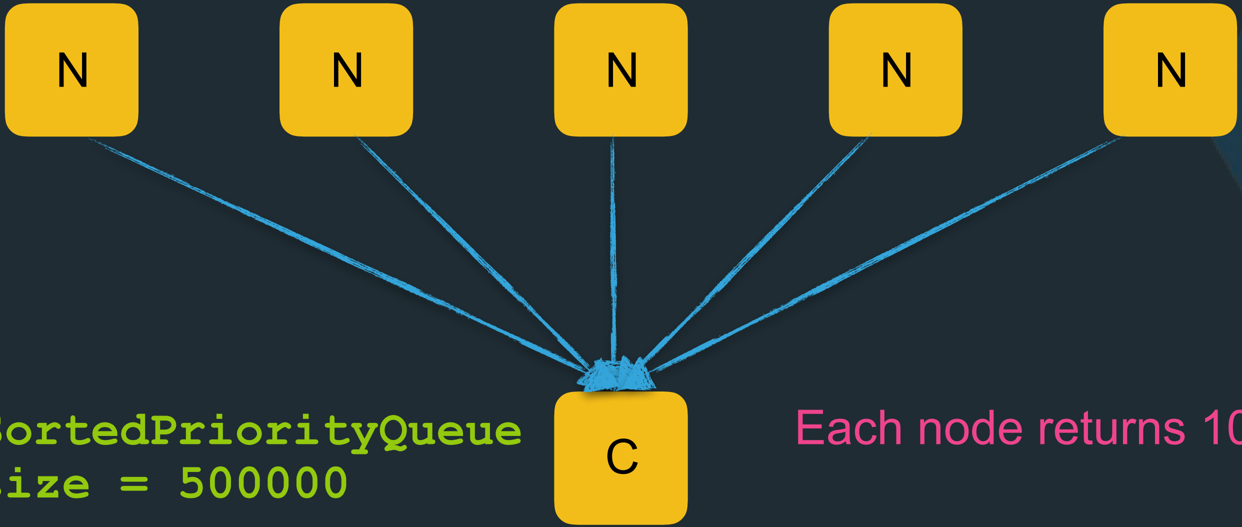
Each node returns 100 results,
create real top 90-100 out of 500

Pagination: Query



Find the 10 results starting at position 99990

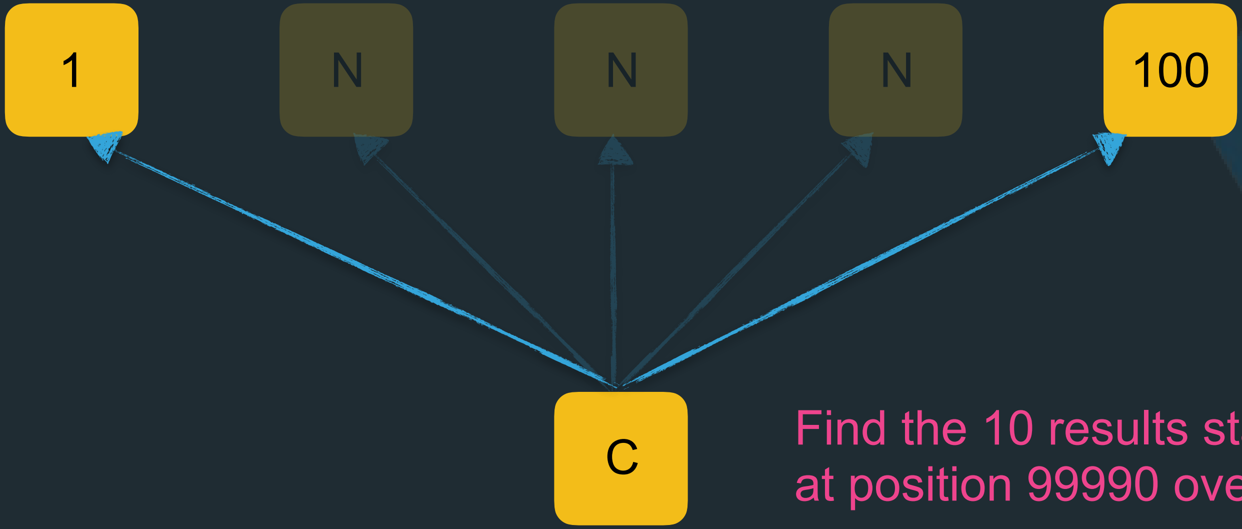
Pagination: Query Phase



`SortedPriorityQueue`
`size = 500000`

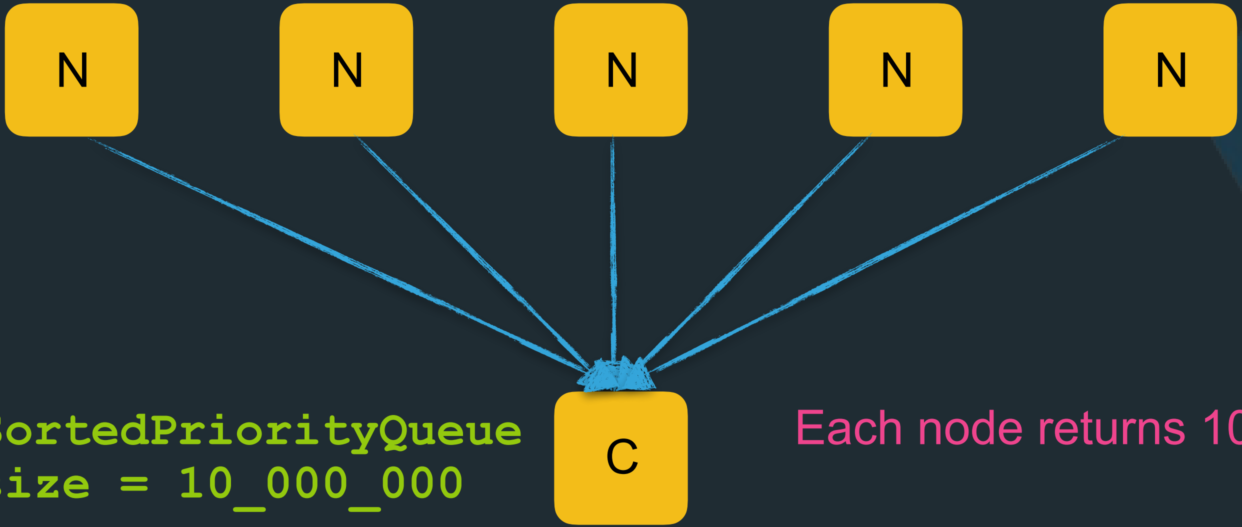
Each node returns 100k results

Pagination: Query



Find the 10 results starting
at position 99990 over 100 nodes

Pagination: Query Phase



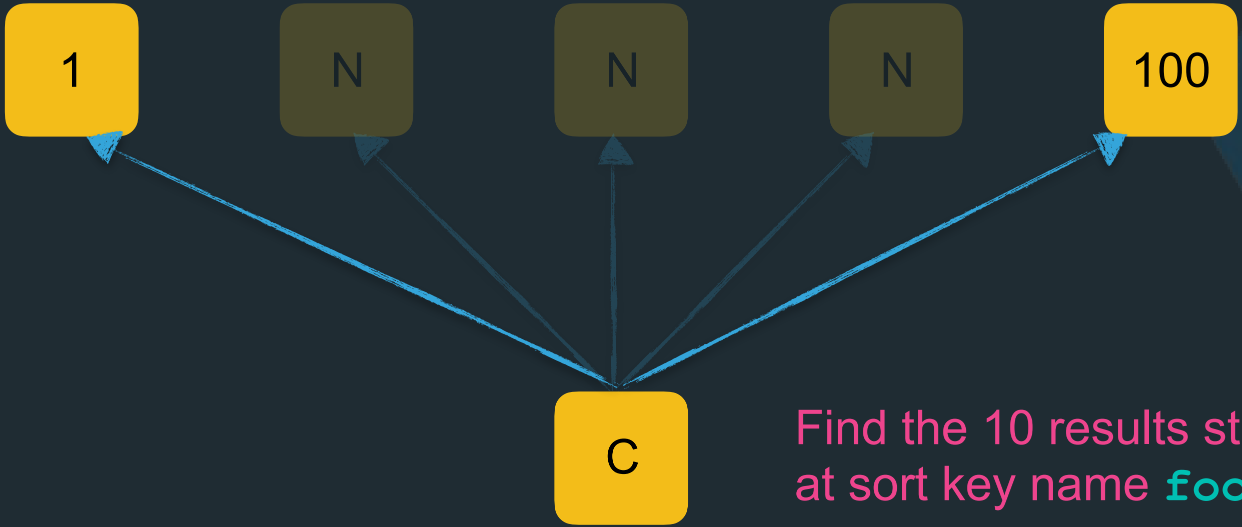
```
SortedPriorityQueue
size = 10_000_000
```

Each node returns 100k results

Solution: search_after

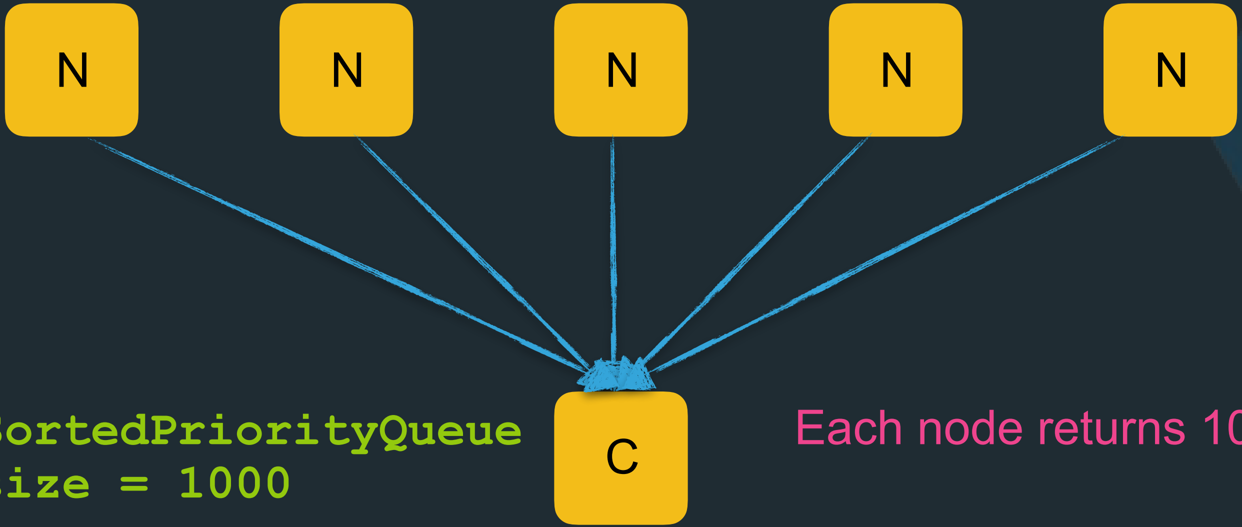
- Do not use numerical positions
- Use keys where you stopped in the inverted index
- Let the client tell you what the last key was
- Just specify the last sort value from the last document returned as a starting point

Pagination: search_after



Find the 10 results starting at sort key name `foo` over 100 nodes

Pagination: search_after



SortedPriorityQueue
size = 1000

Each node returns 10 results

Bonus

replacing delete by query

delete_by_query removal/replace

- `delete_by_query` API was not safe
- API endpoint was removed
- extensive documentation was added what to do instead
- infrastructure for long running background tasks was added
- `delete_by_query` was reintroduced using above infra and doing the exact same thing as in the documentation
- data > convenience!

Thanks for listening!

Questions?

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