Hadoop Security

Kerberos, PAM and LDAP Integration

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Why Security

- Threats and Challenges in unsecured hadoop cluster
  - Absence of service level authentication
  - Lack of ACL at data nodes, once Namenode authorizes access
  - Intermediate Map output is not stored in HDFS; it is stored on the local disk of each compute node
  - In multi-tenant shared environment, tasks of different tenant can execute on same machine, posses unauthorized access threat.
  - Impersonation
  - Unauthorized access of web consoles (namenode, yarn, oozie)

Security Terms

- **SASL**(Simple Authentication and Security Layer)

  Generic framework for authentication and data security, supports GSSAPI

- **GSSAPI**(Generic Security Services API)

  Generic Interface for programs to access security services.

- **SPNEGO**(Simple and Protected GSSAPI Negotiations Mechanism)

  A pseudo mechanism, used when a client application wants to authenticate to a remote server, but neither end is sure what authentication protocols the other supports.

  Needed for authentication of http web-consoles

- **ACL**(Access Control List)

  Handles service and file level authorization

- **PAM(**Pluggable Authentication Modules)

  A common framework for authentication and security

Security terms

- **Kerberos Realm: = Domain**

  Logical grouping of principals

- **Kerberos Principal: = User/Service**

  Identity to use to authenticate to Kerberos server.

- **Delegation token**:

  After initial authentication of the user, these tokens are used to authenticate the user to the services. This reduces the load on the KDC server.

- **Block Access token**:

  Namenode issues Block access tokens that is sent to data nodes for block access requests.

How to secure hadoop cluster

- Authentication
  - Kerberos and SSL
- Authorization
  - File system permission
  - AD level authorization
  - ACL (Access Control List)

Hadoop core services

Service	Description
Namenode	Manages HDFS meta data. Central point of HDFS access
Data node	Manages HDFS data blocks
Yarn Resource Manager	Schedules container execution within a cluster
Yarn Node Manager	Manages container execution and shuffle results on one machine
Job History Server	Manages job history across a cluster

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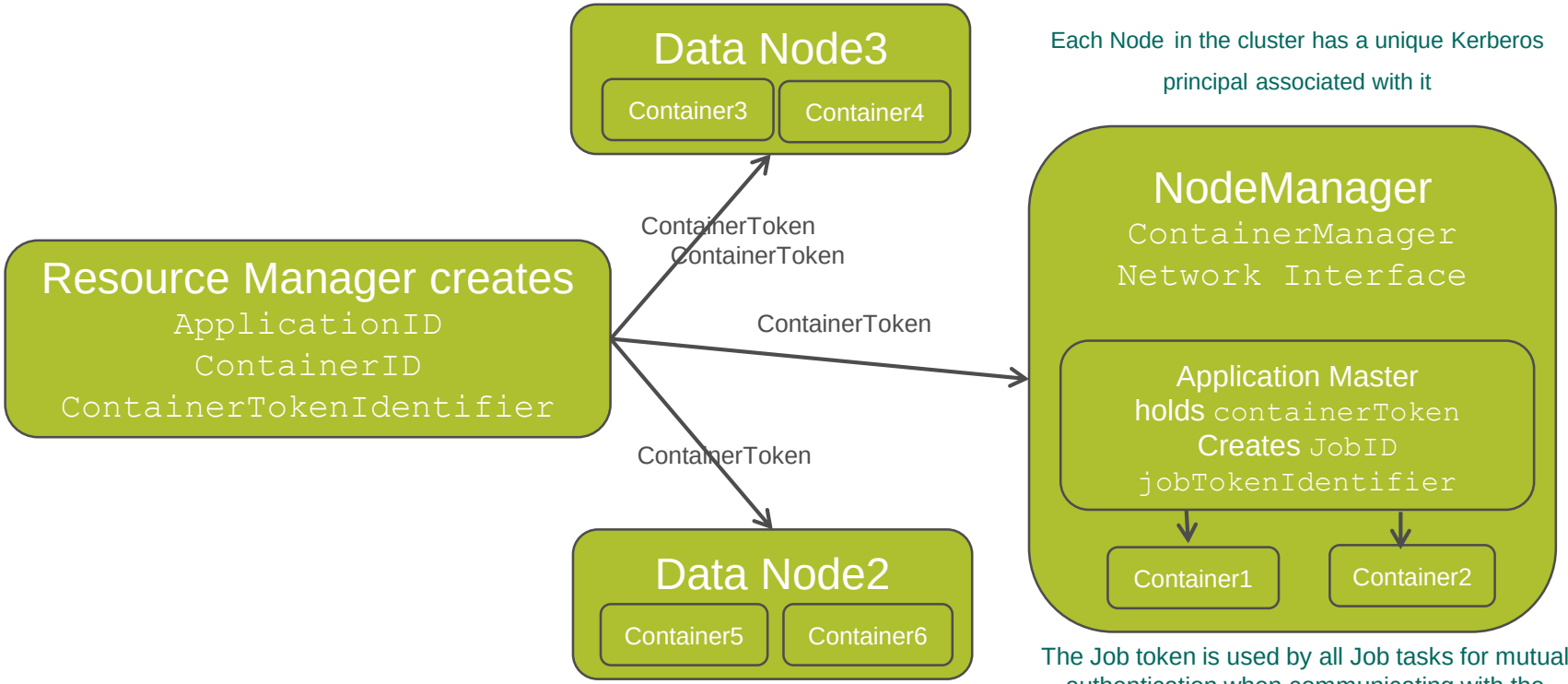
Hadoop Internal Communication



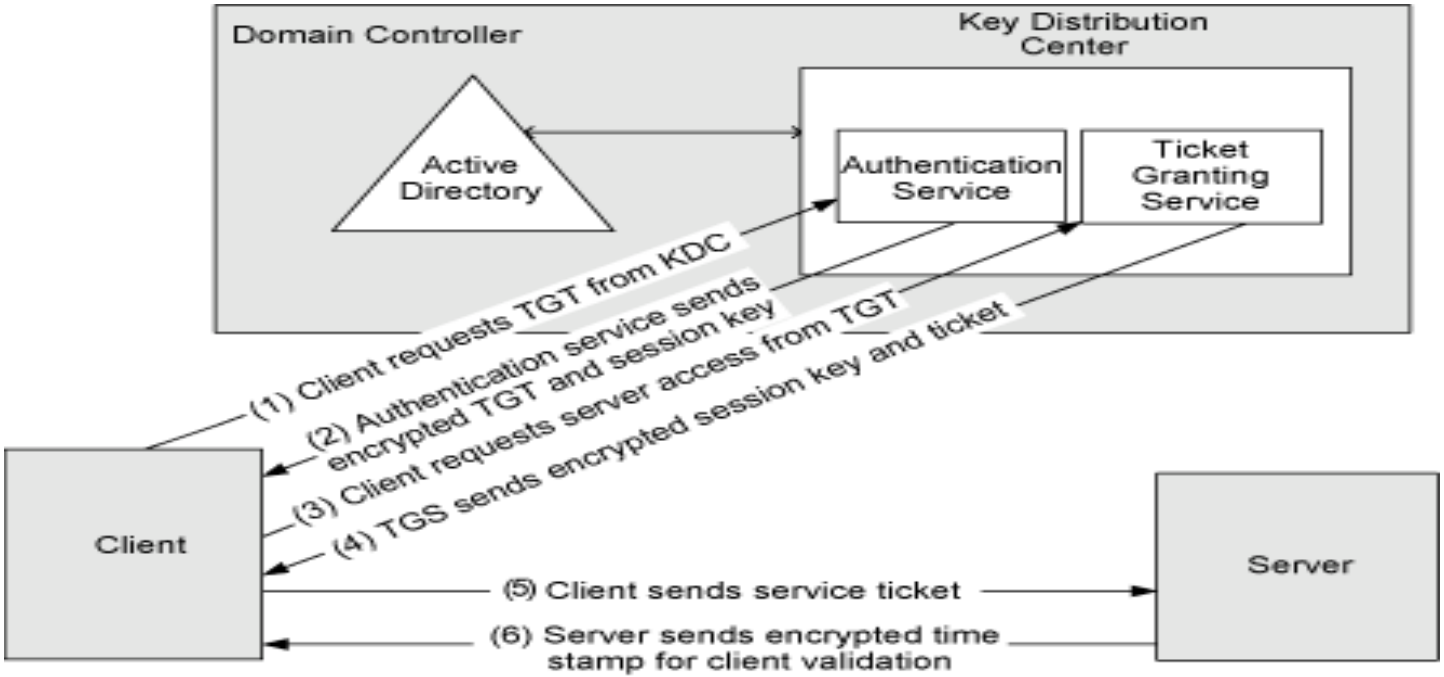
Authentication

- What is Kerberos?
  - Developed by MIT in 1980s as part of project Athena and X Window System.
  - Provides mutual authentication between two nodes/services over an insecure network.
  - Uses symmetric cryptography and need third party trust(KDC).

    Same cryptographic keys for both encryption of plaintext and decryption of cipher text.
  - Provides authenticated access for users and services.
  - Uses ticket based authentication
  - Password is not stored or transmitted over network
  - Can define secondary Kerberos server to deal with primary server failure
  - Can be integrated with AD/LDAP.

How Kerberos works?

Image Source



Securing Hadoop using Kerberos

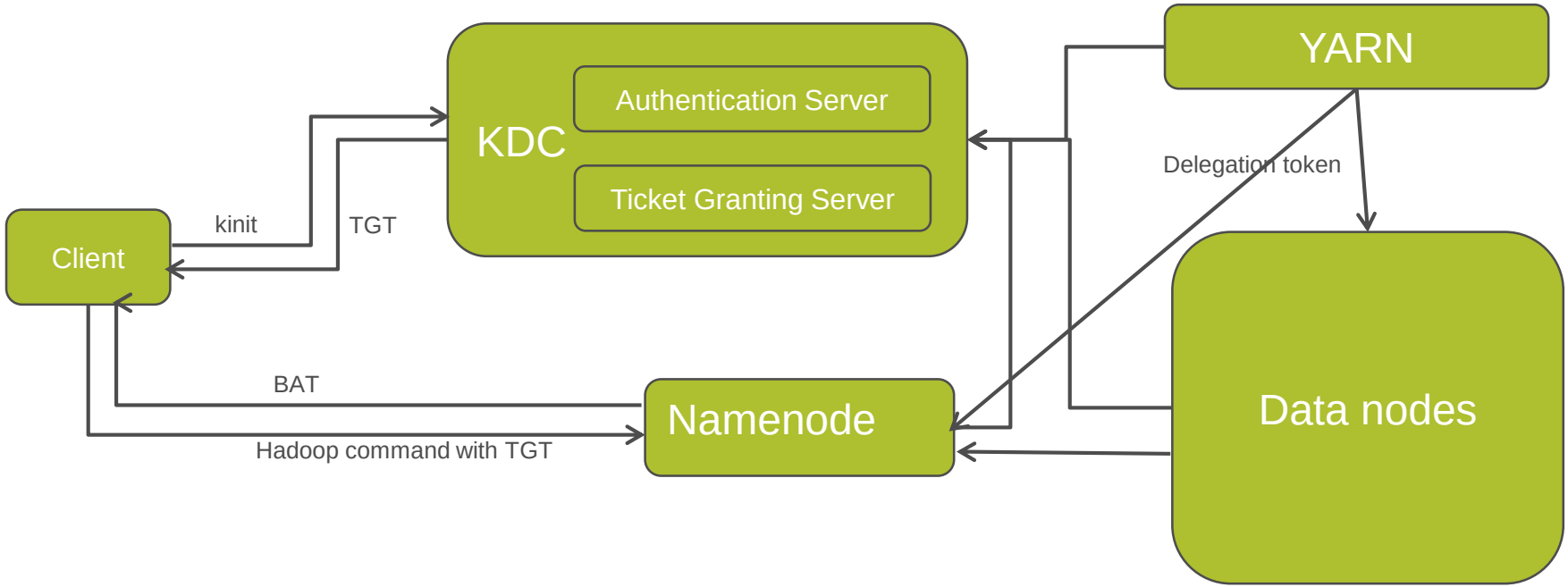
- In hadoop, Kerberos is used to perform 2 types of mutual authentication.
  - Client – Service Authentication

    Required for client authentication with services that issue delegation token. Can also be used with other Services using proxy user.
  - Service – Service Authentication
- Client access most Hadoop services via Hadoop's RPC library
- For authenticated clusters, all RPC's connect using Simple Authentication and Security Layer (SASL). SASL negotiates a sub-protocol to use and Hadoop will support either using Kerberos (via GSSAPI) or DIGEST-MD5. Most applications run on the gateways use Kerberos tickets, while tasks in MapReduce jobs use tokens.
- The user gets a service ticket for the service and authenticates using SASL/GSSAPI. This is the standard Kerberos usage and mutually authenticates the client and the server.

Securing Hadoop using Kerberos

- The client loads any Kerberos tickets that are in the user's ticket cache. MapReduce also creates a token cache that is loaded by the task. When the application creates an RPC connection, it uses a token, if an appropriate one is available. Otherwise, it uses the Kerberos credentials.
- There are two important mechanisms that affect how users and groups are determined for a given user
  - First there is a mapping between Kerberos principal and a simple username. This mapping is handled by mapping rules provided in coresite.xml configuration file for property hadoop.security.auth_to_local
  - The second is the mapping of a user to a set of groups. This is handled via a plugin implementation of the GroupMappingServiceProvider.
- Common Kerberos commands: kadmin, kadmin.local, klist, kdestroy, addprinc, getpric, ktadd
- Make sure service/user principal kvno matches.

Securing Hadoop using Kerberos



Technical Details

- To setup Kerberos server install `krb5-libs, krb5-workstation, and krb5-server`
- Install `krb5-libs, krb5-workstation` on all cluster nodes.
- Create Kerberos configuration file, default file is /etc/krb5.conf
- Distribute Kerberos configuration on all cluster nodes
- Create principals for all required services for all hosts.
- Distribute principals to corresponding hosts.
- Edit hadoop configuration files e.g. `hdfs-site.xml` and `core-site.xml` to enable Kerberos security, add service principal and keytab properties.
- Restart cluster and make sure all processes are running fine.
- All nodes should have access to KDC, DNS should work fine and clock should be in sync.
- Make sure OS version, Java version and Kerberos Version is compatible.

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Kerberos principal examples:

```
<property>
   <name>dfs.namenode.kerberos.http.principal</name>
   <value>HTTP/_HOST@YOUR_COMPANY.REALM_COM</value>
</property>
 <property>
   <name>dfs.namenode.keytab.file</name>
   <value>/etc/security/phd/keytab/hdfs.service.keytab</value>
</property>
 <property>
   <name>dfs.journalnode.kerberos.http.principal</name>
   <value>HTTP/_HOST@YOUR_COMPANY.REALM_COM</value>
</property>
 <property>
   <name>dfs.datanode.kerberos.principal</name>
   <value>hdfs/_HOST@YOUR_COMPANY.REALM_COM</value>
</property>
```

krb5.conf example

```
[libdefaults]
        default_realm = ATHENA.MIT.EDU
        default_tkt_enctypes = des3-hmac-sha1 des-cbc-crc
         default_tgs_enctypes = des3-hmac-sha1 des-cbc-crc
         dns_lookup_kdc = true
         dns_lookup_realm = false
    [realms]
         ATHENA.MIT.EDU = {
             kdc = kerberos.mit.edu
             kdc = kerberos-1.mit.edu
             kdc = kerberos-2.mit.edu:750
             admin_server = kerberos.mit.edu
             master_kdc = kerberos.mit.edu
             default_domain = mit.edu
         }
         EXAMPLE.COM = {
             kdc = kerberos.example.com
             kdc = kerberos-1.example.com
             admin_server = kerberos.example.com
         }
[domain_realm]      =>   Maps server hostnames to Kerberos realms
         .mit.edu = ATHENA.MIT.EDU
         mit.edu = ATHENA.MIT.EDU
```

Integrating kerberos with AD

- Set up one-way cross-realm trust from Kerberos realm to the Active Directory realm
  - Add Kerberos realm and hostname in Active Directory
  - Add Kerberos realm trust in Active directory
  - Set encryption type for the Kerberos realm and make sure the selected encryption is supported by both AD and KDC.
  - Add krbtgt principal for cross-realm trust on KDC server
  - Add AD realm along with Kerberos realm in krb5.conf file on all nodes
  - Configure `hadoop.security.auth_to_local` in `core-site.xml` to translate AD principals to local names in hadoop.

Authorization

- Service Level Authorization
  - Service Level Authorization is performed much before to other access control checks such as file-permission checks, access control on job queues etc.
  - Access control list for all hadoop services is defined in `hadoop-policy.xml` file.
  - To enable service level authorization, hadoop.security.authorization property must be set to true in `core-site.xml` file.
  - HDFS file level ACL will be supported from hadoop version 2.4

Authorization

Examples:

- Allow only users John, Mark and users in the mapreduce group to submit jobs to the MapReduce cluster:

```
<property>
     <name>security.job.submission.protocol.acl</name>
      <value>john,mark mapreduce</value>
</property>
```

- Allow only DataNodes running as the users who belong to the group datanodes to communicate with the NameNode:

```
<property>
      <name>security.datanode.protocol.acl</name>
      <value>datanodes</value>
</property>
```

Authorization

- Job queue ACLs
  - Controls who can submit jobs to a queue, kill jobs, or modify their priority
  - `mapred.acls.enabled` should be set to true in mapred-site.xml
  - ACLs should be defined in `mapred-queue-acls.xml` file.

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