MD-SAL Application Development

MD-SAL Java Background, Environment, and Tools

Software Requirements

- JDK 1.7+
  - Set JAVA_HOME
- Maven 3.1+
  - Set MAVEN_HOME
  - repository: Where dependencies are downloaded and placed
  - settings.xml: Points Maven to where repositories are located
- Git
  - Install Git Client, e.g., Source Tree
- IDE
  - Intellij IDEA
  - Eclipse

Maven

```
<profile>
  <id>opendaylight-release</id>
  <repositories>
    <repository>
      <id>opendaylight-mirror</id>
      <name>opendaylight-mirror</name>
      <url>http://nexus.opendaylight.org/content/repositories/public/</url>
      <releases>
        <enabled>true</enabled>
        <updatePolicy>never</updatePolicy>
      </releases>
      <snapshots>
        <enabled>false</enabled>
      </snapshots>
    </repository>
  </repositories>
  <pluginRepositories>
    <pluginRepository>
      <id>opendaylight-mirror</id>
      <name>opendaylight-mirror</name>
      <url>http://nexus.opendaylight.org/content/repositories/public/</url>
      <releases>
        <enabled>true</enabled>
        <updatePolicy>never</updatePolicy>
      </releases>
      <snapshots>
        <enabled>false</enabled>
      </snapshots>
    </pluginRepository>
  </pluginRepositories>
</profile>
.................
 <activeProfiles>
    <activeProfile>opendaylight-release</activeProfile>
    <activeProfile>opendaylight-snapshots</activeProfile>
 </activeProfiles>
```

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Maven

Some common pre-defined goals:

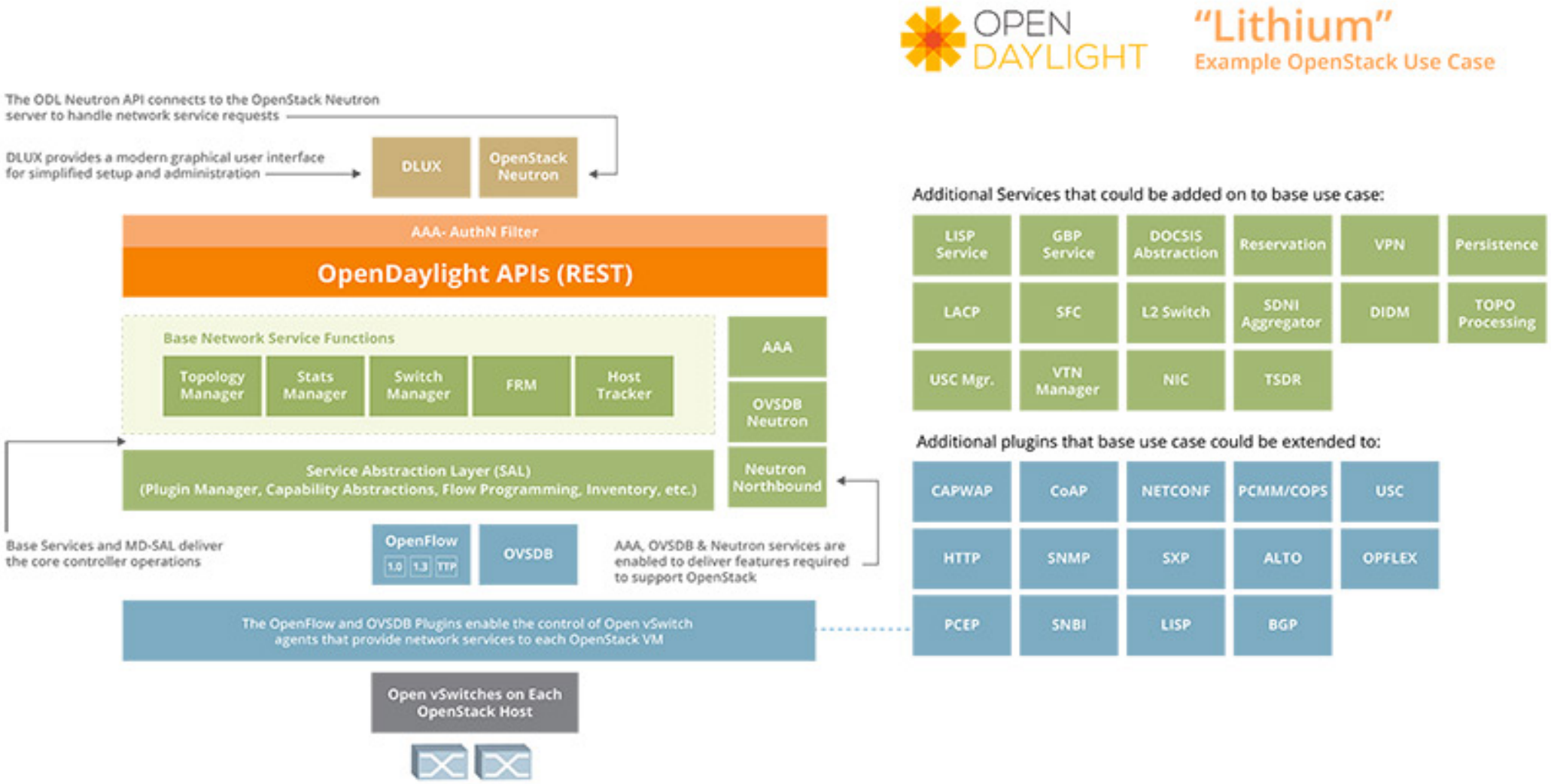
- clean: clean up working directory of files that were created at build time.
- install: install the built artifact(s) as directed
- -DskipTests: don’t running the tests for this build

maven.apache.org

set MAVEN_OPTS=-Xmx512m -XX:MaxPermSize=128m

ODL Architecture

ODL Architecture



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Controller Platform/Framework

- 采用了OSGI Framework，实现了模块化和可扩展化
- SAL是Controller Platform的最核心模块
- 由运行在OSGI Framework上的Bundle实现
- 控制模块间数据交互，数据存取，API调用

Northbound REST

- 可扩展
- REST是以资源的角度观察整个网络，分布在各处的资源由URI确定
- 目的是为不同地址空间的应用提供接口; 应用可能是多样性的

Southbound Netty

- 南向接口支持多种协议; 这些协议模块以插件的方式动态挂在SAL上
- 南向接口使用Netty来管理底层的并发IO
- Netty是提供异步的、事件驱动的网络应用框架; 该框架健壮性、扩展性良好，而且还具有延时低、节省资源等特点

Plugin

- 通过SAL实现的功能模块
- 运行在ODL OSGI Framework上，与ODL控制器共享同一个JVM资源
- Southbound Plugin
  - 向SAL提供管理控制南向设备或服务的操作接口
- Northbound Plugin
  - 通过利用SAL所提供的北向服务API向应用提供统一的抽象服务和相应的API

Karaf

OSGI(Open Services Gateway Initiative)

- 通俗点说JAVA动态模块系统，定义了一套模块应用开发的框架
- OSGI容器允许把应用分成多个功能模块，通过依赖管理这些功能会更方便
- Bundle 是 OSGi 中的基本组件，其表现形式仍然为Java概念中传统的Jar

Karaf

- Karaf中引用了Feature的概念; Feature是符合某个功能特性的bundle集的部署描述

  A feature describes an application as:
  - a name
  - a version
  - an optional description (eventually with a long description)
  - a set of bundles
  - optionally a set configurations or configuration files
  - optionally a set of dependency features

Karaf

The directory layout of a Karaf installation is as follows:

- /bin: control scripts to start, stop, login, ...
- /demos: contains some simple Karaf samples
- /etc: configuration files
- /data: working directory
- /cache: OSGi framework bundle cache
- /generated-bundles: temporary folder used by the deployers
- /log: log files
- /deploy: hot deploy directory
- /instances: directory containing instances
- /lib: contains libraries
- /lib/boot: contains the system libraries used at Karaf bootstrap
- /lib/endorsed: directory for endorsed libraries
- /lib/ext: directory for JRE extensions
- /system: OSGi bundles repository, laid out as a Maven 2 repository

Karaf Commands

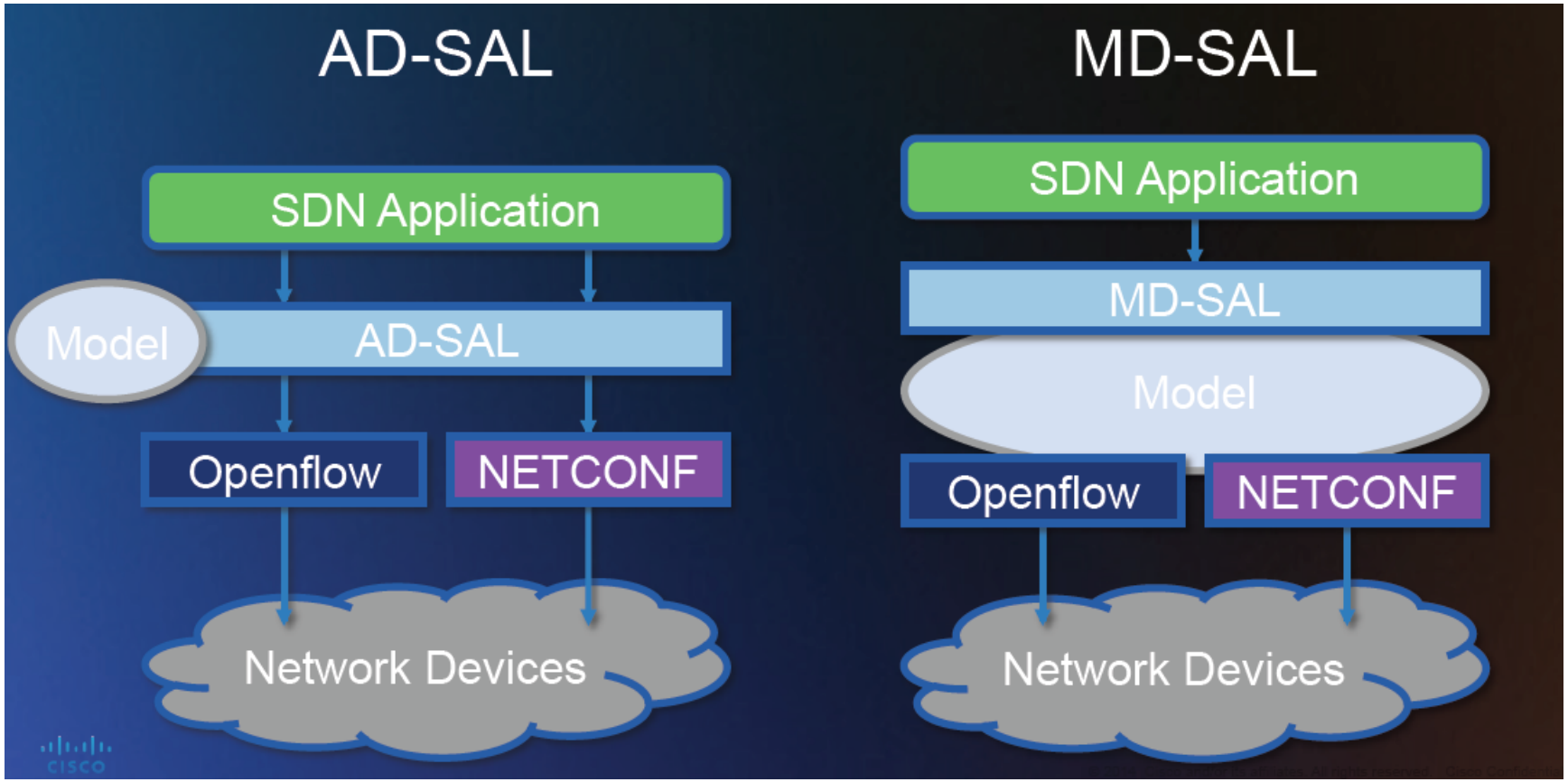
- Logging
  - log:display - Displays the entire log
  - log:tail - Continuously displays the last lines of the log
- Features
  - feature:list - Lists all the features known to the controller (installed or not)
  - feature:install - Installs a feature
- Repository
  - repo:mvn... - Specifies a repository in which Karaf will look for features

karaf.apache.org/manual/latest/commands/commands.html

MD-SAL

Why MD-SAL: Model-based

- Operations based on model:
  - Applications interact with the model; model interacts with the network.
  - This abstraction allows for any (or multiple) southbound plugin(s).



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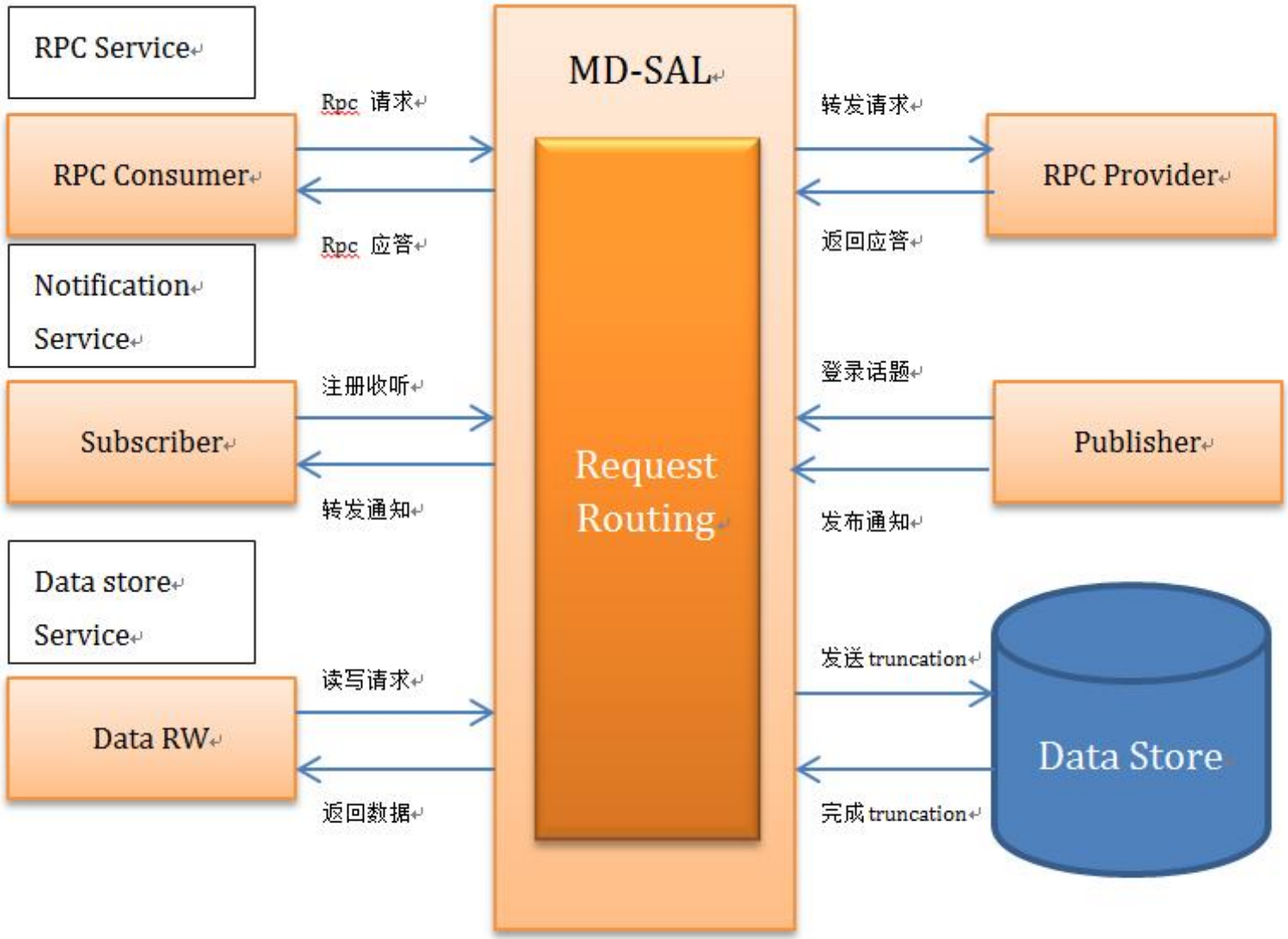
Overview

- 简单的说，MD-SAL是一套基础设施服务，为Apps和Plugins开发提供通用支持
- 提供Request Routing和用来实现抽象服务和相应API的基础框架
  - 抽象服务和相应API是由各个Plugin通过Yang Model和Service来定义
  - Yang Tools Plugin通过各个Plugin的Model定义来自动生成API、Service Interface和相应Java代码
  - 开发者通过实现自动生成的Service Interface来实现具体的API和服务内容
  - Plugin通过MD-SAL和生成的API（RPC, Notification）、DataStore去利用其他各个Plugin的服务和数据
- 所有功能模块的信息交互，数据存储调用都通过MD-SAL完成

Function

MD-SAL的主要功能就是管理基于Yang Model定义的各种Plugin。

- RPC：提供服务的远程Call接口
- Notification：提供Notification收听，发行等功能
- Data Store：提供数据存储，读取，Transaction等功能
- Request Routing：提供请求路由功能，把外部的请求传送到正确的Plugin和Node Instance处理
  Node instance是Yang结构树上的节点实例。
- RestConf Subsystem：自动定义和创建RestConf API的Plugin
- Config subsystem：提供统一的配置文件管理功能的Plugin



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MD-SAL Plugin

根据Plugin和MD-SAL的关联方式，Plugin分为如下两种

- BA（Binding-Aware）

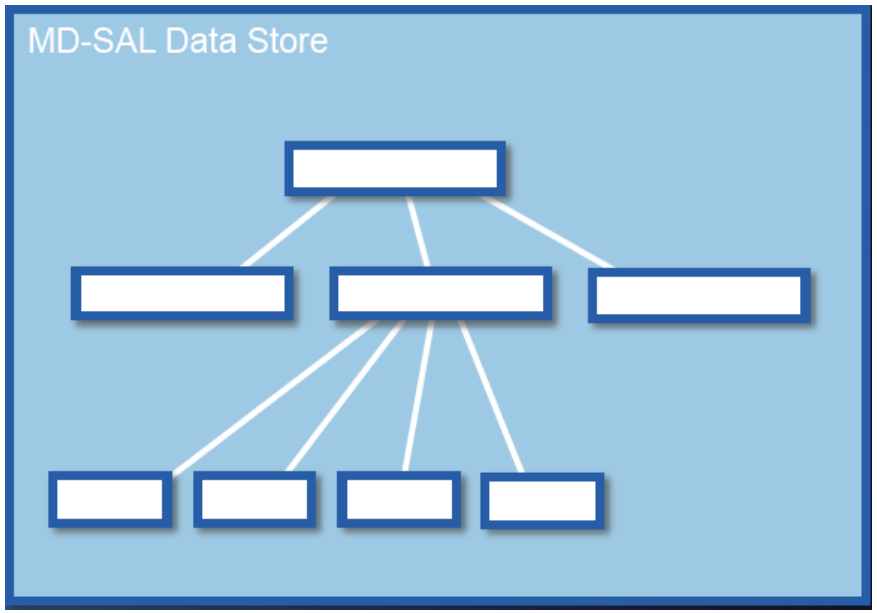
指使用根据Yang Model定义而自动生成的Java Bindings的Plugin

- BI（Binding-independent）

与BA相反，不依赖于Java Bindings的Plugin

YANG Models

YANG Data Tree



Why is this important?

- **Storage:** You will be *storing* data into the MD-SAL Data Store using the Data Broker
- **Event notifications:** You will be *listening* for notifications indicating that somebody or something has changed data associated with your model.

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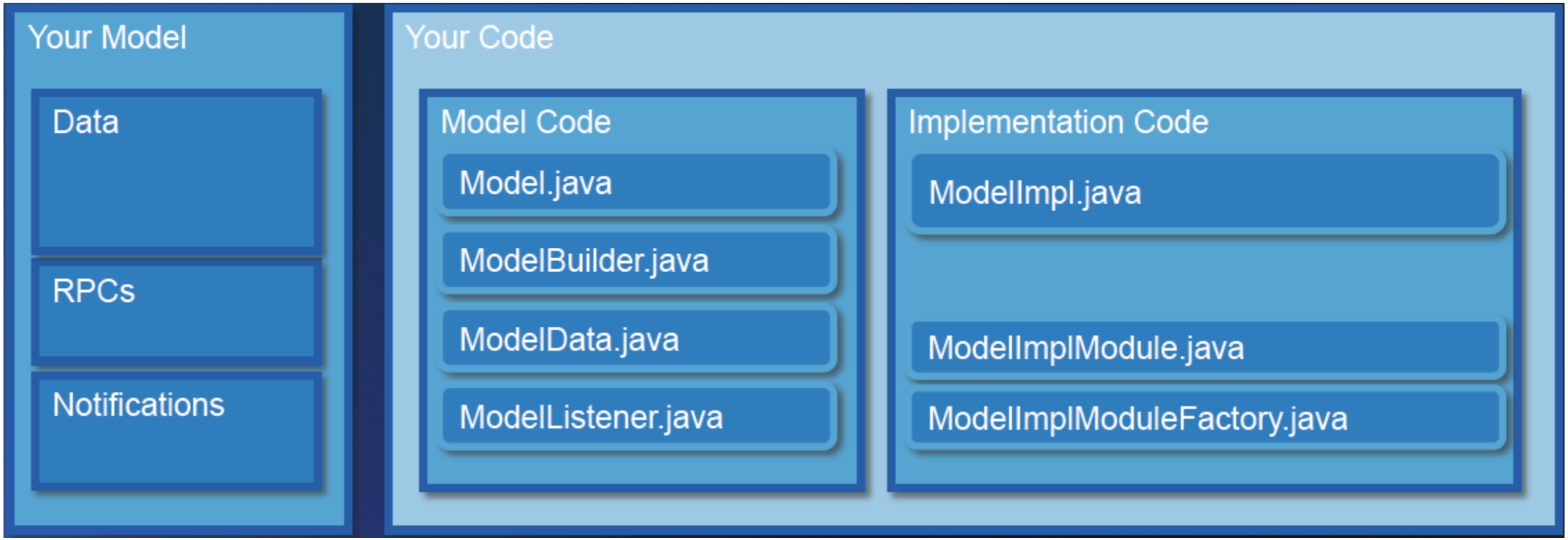
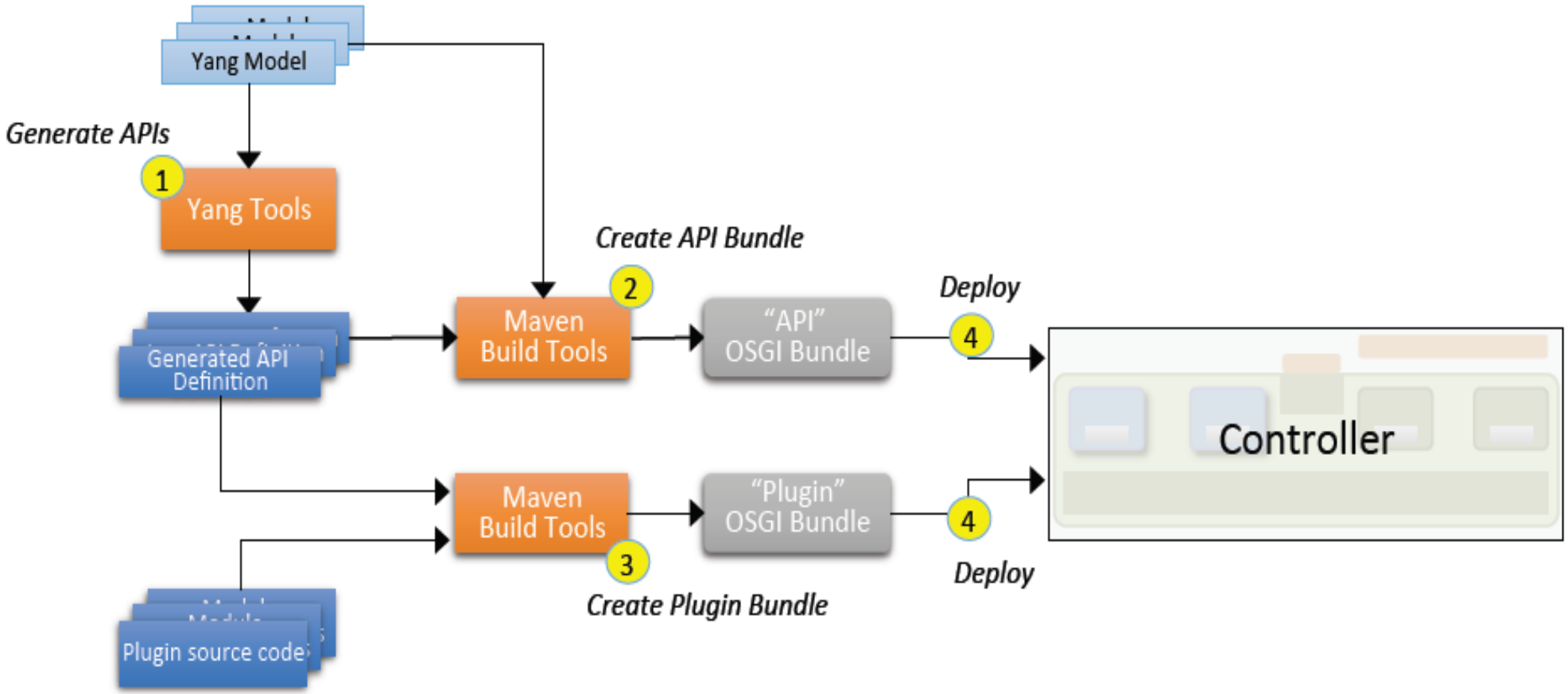
Model-generated Code



YANG Tools

How MD-SAL Works: Auto-generated Model and API

- Define you application’s model using YANG
- Compile model
- Model code auto-generated
- REST API code auto-generated
- You implement business logic



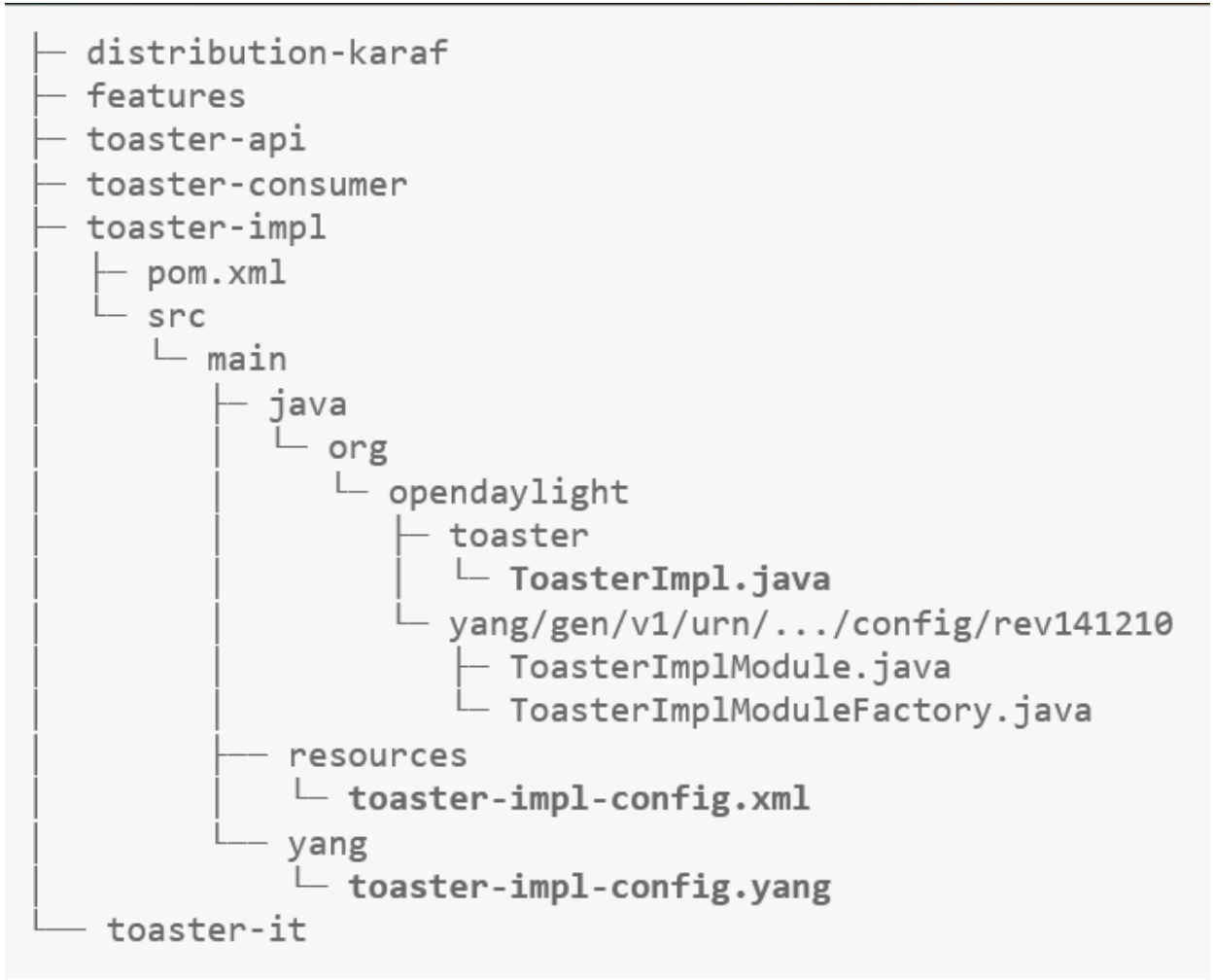
MD-SAL Core Tutorials

First Sample Application

Connecting Your Application to Controller

Three connection points:

- **Model:** YANG model for 'impl' informs controller of your configuration files.
- **Configuration:** Configuration file for 'impl' identifies the MDSAL broker with which you will be working.
- **Code:** Your 'impl' code will implement methods to initialize our Toaster application
  - **createInstance()** in ToasterImplModule class
  - **onSessionInitiated()** in ToasterImpl class



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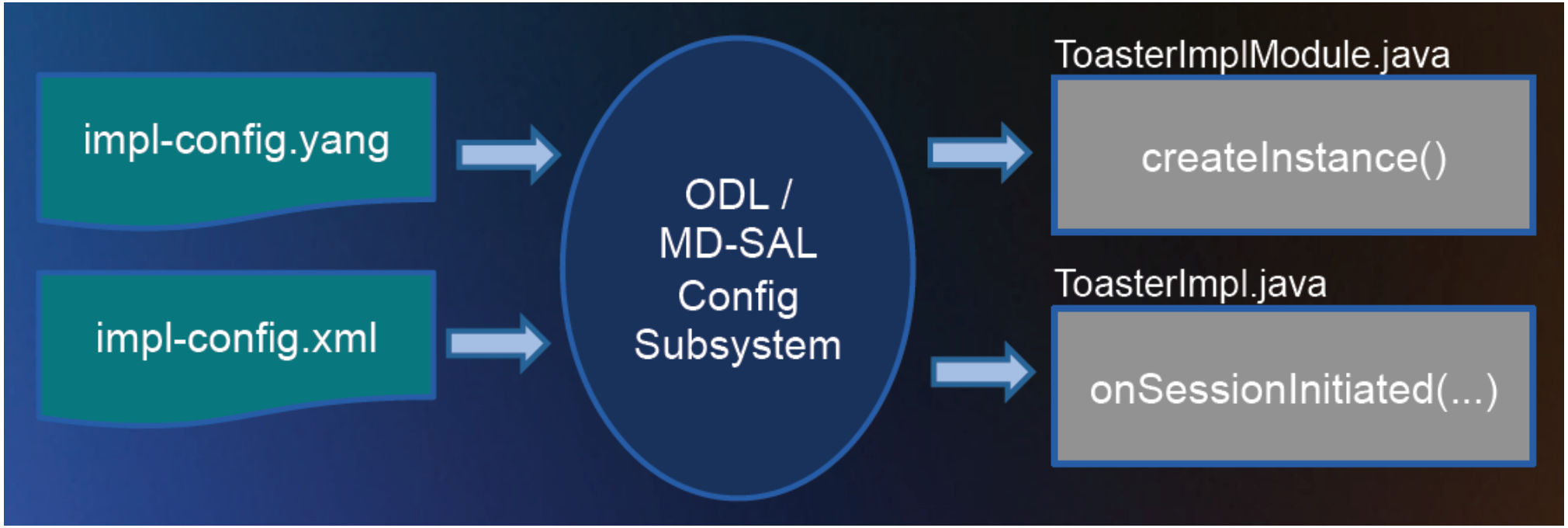
Wiring Application to MD-SAL

- **YANG:** Defines wiring details
- **Config:** Defines dependencies
- **Code:** Handles initialization process

- **createInstance:** called when our module is created.
- **onSessionInitiated:** called when our provider is created and registered



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Initializing Your Application

ToasterImplModule:

- **createInstance():** Override ‘createInstance’ in ToasterImplModule
- **Called by controller:** ‘createInstance’ called by controller when app starts
- **Create your ‘provider’ :** Create your provider, i.e. your toaster implementation, called ‘ToasterImpl’
- **Register your provider:** Register your provider with controller

ToasterImplModule.java

```
@Override
public java.lang.AutoCloseable createInstance() {

    ToasterImpl provider = new ToasterImpl();
    getBindingAwareBrokerDependency().registerProvider( provider, null );

    return provider;
}
```

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Initializing Your Application

ToasterImpl:

- **onSessionInitiated:** Override ‘onSessionInitiated’
- **Called by controller:** Called by controller when your provider starts up and is registered in ‘createInstance()’
- For sample application: just log a ‘hello world’ message

ToasterImpl.java

```
@Override
public void onSessionInitiated( ProviderContext context ) {

    LOG.info("Hello World!");

}
```

Yang

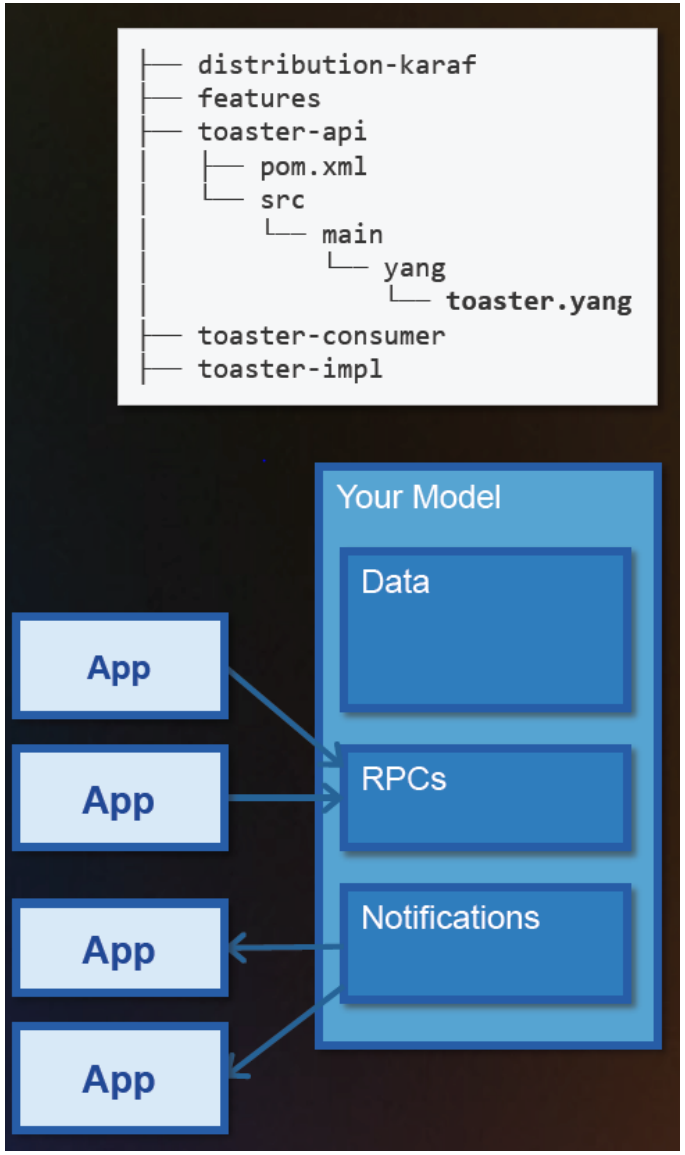
YANG Definitions

YANG - Defining your application:

- **Directory - toaster-api**: where the YANG definition of your application' s model resides
- **src/main/yang/toaster.yang**: the actual YANG file that holds the application details.

YANG - Components:

- **Data:** defines the information that comprises your application. Identification, status, lists of stored items, etc.
- **RPCs:** Operations (APIs) that can be invoked on your model, such as tasks to be performed, status information to be retrieved, etc.
- **Notifications:** Messages that will be sent by this model object to registered listeners, informing them of state changes, new items created, deleted, changed, etc.



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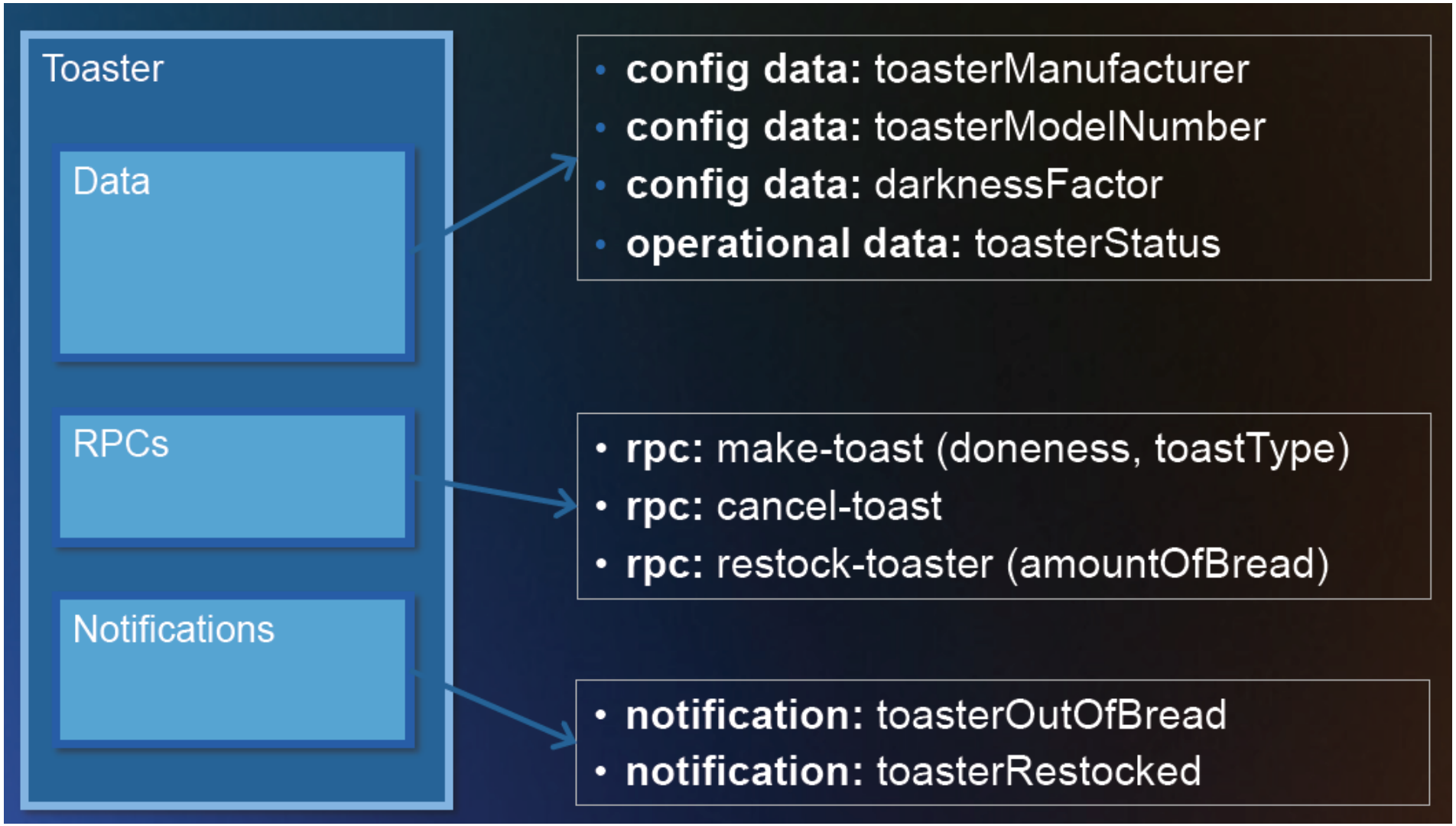
YANG Toaster Definition



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Features Definition for our Model

Feature definition in features.xml

- **Name:** Defines feature ‘odl-toaster-api’
- **Dependencies:** Includes dependencies on:
  odl-yangtools-common
  odl-yangtools-binding
  odl-restconf
- **Bundle:** A bundle is built from files in this folder

```
<feature name='odl-toaster-api' version='${project.version}' description=...'>

     <feature version='${yangtools.version}'>odl-yangtools-common</feature>
     <feature version='${yangtools.version}'>odl-yangtools-binding</feature>
     <feature version='${controller.restconf.version}'>odl-restconf</feature>

     <bundle>mvn:org.opendaylight.toaster/toaster-api/${project.version}</bundle>

</feature>
```

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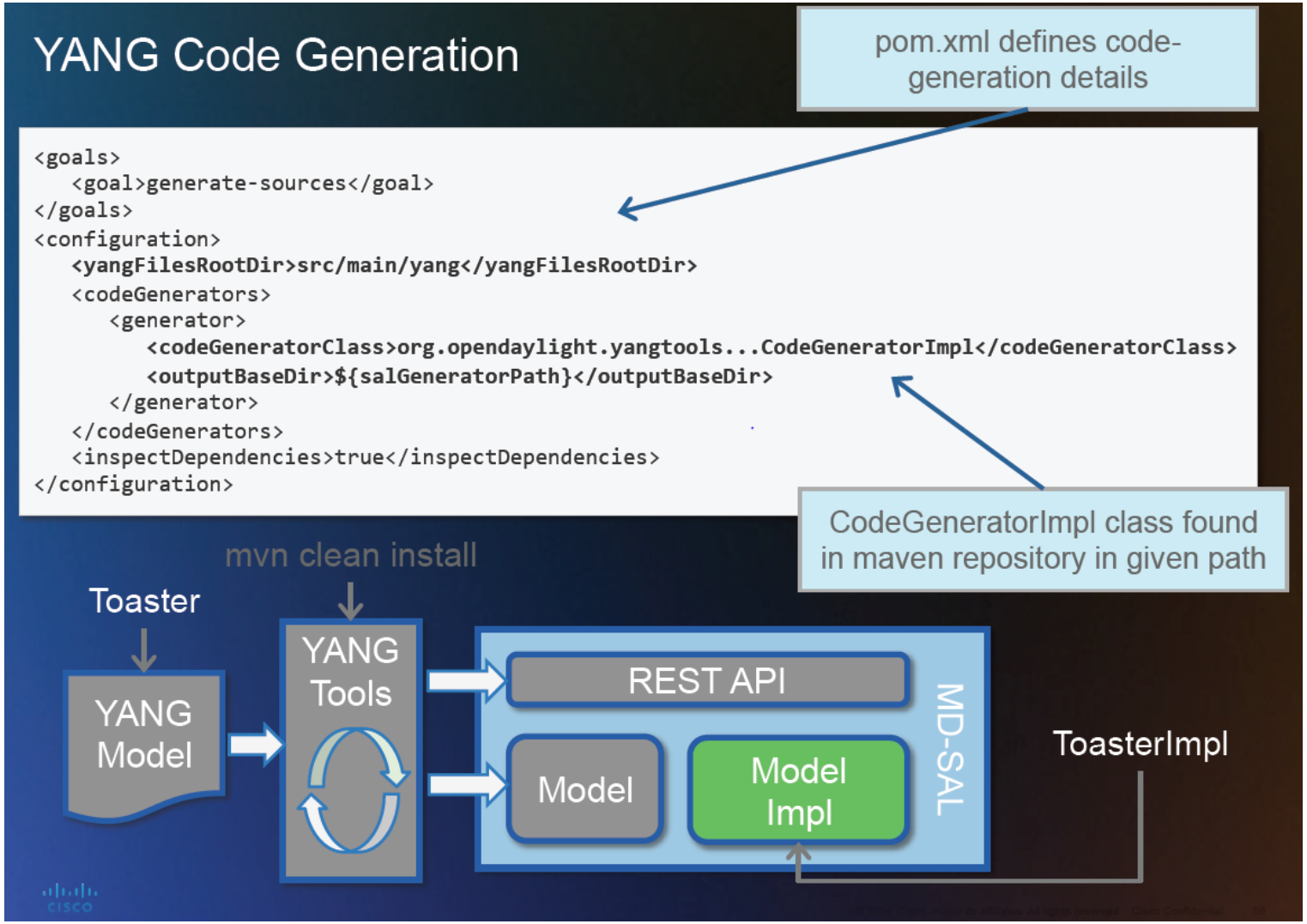
Reading Model Data

YANG Code Generation



Generated Code

toaster-api/target/generated-sources/sal: Generated code placed in this directory

- ***.java:** Java files created out of YANG model definitions
- **Container:** YANG definition of *toaster* becomes Java interface *Toaster*
  - Includes interface for getting *ToasterStatus, Manufacturer, ModelNumber*
  - Includes definition for possible ToasterStatus values (*Up, Down*)
- **Identities:** YANG definition for various *toast-types* become abstract classes
  - *wheat-bread* becomes abstract class *WheatBread*
  - *whole-bread* becomes abstract class *WholeBread*
  - *frozen-bagel* becomes abstract class *FrozenBagel*
  - etc.
- **RPCs** and **Notifications:** Covered later

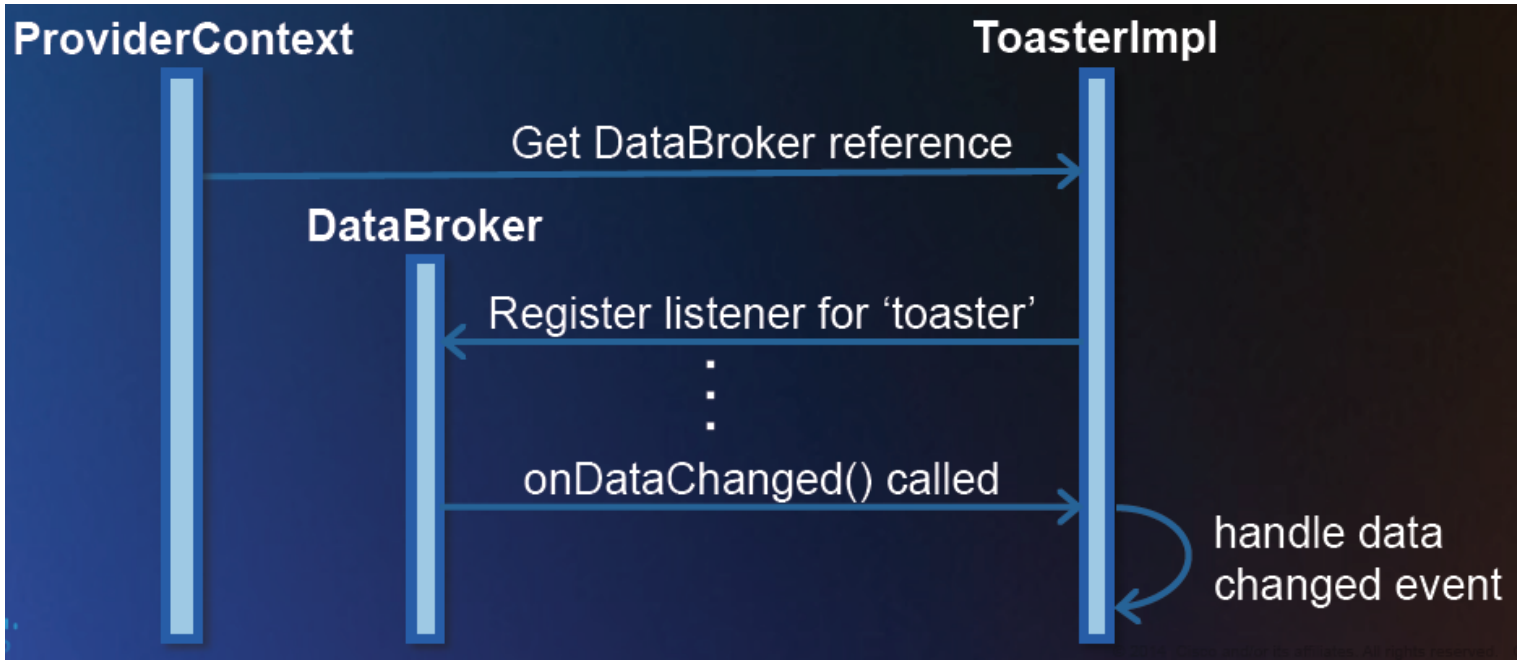
Getting Data Change Notifications from MD-SAL

Receiving notifications of changes to data in MD-SAL data store

- **Data Broker:** The MD-SAL ‘DataBroker’ is your interface to the MD-SAL data store.

Steps for receiving data change notifications

- **DataBroker reference:** get reference to DataBroker
- **Register listener:** register listener for changes to your model objects
- **Handle notifications:** receive notification via the *onDataChanged()* method



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Registering Listener

Instance Identifier:

• Create Instance Identifier (‘IID’) for your model object (Toaster.class)

```
public static final InstanceIdentifier<Toaster> TOASTER_IID =
                                                InstanceIdentifier.builder(Toaster.class).build();
```

Register Listener with DataBroker: *registerDataChangeListener(...)*

- Data type: *CONFIGURATION* or *OPERATIONAL*
- Instance Identifier: IID of model item in YANG data tree (Toaster)
- Location: in what object is this listener (‘this’, i.e. your ToasterImpl)
- Scope: *BASE* (this object only), *ONE* (this object plus one level below), or *SUBTREE* (this object plus all of its descendants)

```
dcReg = dataService.registerDataChangeListener( LogicalDatastoreType.CONFIGURATION,
                                                TOASTER_IID,
                                                this,
                                                DataChangeScope.SUBTREE );
```

Data Change Notifications

Handling data change notifications

1. **DataChangeEvent:** You receive an AsyncDataChangeEvent ('change')

2. **Get new data:** Retreive changes to your model objects ('getUpdatedSubtree')

3. **Coerce data into Toaster:** Assign updated subtree to your model object ('toaster')

```
@Override
public void onDataChanged( final AsyncDataChangeEvent<InstanceIdentifier<?>, DataObject> change ) {

    DataObject dataObject = change.getUpdatedSubtree();

    if( dataObject instanceof Toaster ) {
        Toaster toaster = (Toaster) dataObject;
        LOG.info("onDataChanged - new Toaster config: {}", toaster);
    }
    else {
        LOG.warn("onDataChanged - not instance of Toaster {}", dataObject);
    }

}
```

1

2

3

4

Writing Model Data

Transactions

General process for writing data to the model using transactions

1. **Data:** Create your data using YANG-generated builder and setter methods
2. **Create:** Create the empty write transaction using data broker service
3. **Put:** Populate the write transaction with your data
4. **Submit:** Submit your transaction

```
Toaster toaster = new ToasterBuilder().setToasterManufacturer( TOASTER_MANUFACTURER )
                                      .setToasterModelNumber( TOASTER_MODEL_NUMBER )
                                      .setToasterStatus( ToasterStatus.Up )
                                      .build();

WriteTransaction tx = dataService.newWriteOnlyTransaction();

tx.put(LogicalDatastoreType.OPERATIONAL, TOASTER_IID, toaster);

tx.submit();
```

1 2 3 4

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Asynchronous Operation

General process for asynchronous operation:

1. Create and populate transaction, but don't *submit*

2. Submit transaction using Futures class

3. Create anonymous class for asynchronous completion of task

    - Override *onSuccess* and *onFailure* in *Futures.addCallback(...)*

```
Toaster toaster = new ToasterBuilder(). ... .build();
WriteTransaction tx = dataService.newWriteOnlyTransaction();
tx.put(LogicalDatastoreType.OPERATIONAL, TOASTER_IID, toaster);

Futures.addCallback( tx.submit(), new FutureCallback<Void>() {
            @Override
            public void onSuccess(final Void result) {
                LOG.info("initToasterOperational: transaction succeeded");
            }
            @Override
            public void onFailure(final Throwable t) {
                LOG.error("initToasterOperational: transaction failed");
            }
} );
```

1

2

3

Synchronous vs Asynchronous

Write transaction (synchronous):

- Call ‘submit’ method

```
tx.submit();
```

Write transaction (asynchronous):

- Call ‘addCallback’ method of ‘Futures’ static class
- Pass in ‘tx.submit()’, and create a new ‘FutureCallback’ object
- Override ‘onSuccess’ and ‘onFailure’ in FutureCallback object

```
Futures.addCallback( tx.submit(), new FutureCallback<Void>() {
            @Override
            public void onSuccess(final Void result) {
                LOG.info("initToasterOperational: transaction succeeded");
            }
            @Override
            public void onFailure(final Throwable t) {
                LOG.error("initToasterOperational: transaction failed");
            }
} );
```

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Anonymous Class: Alternative

Anonymous classes:

- Purpose is to simplify, but often degrades readability
- Alternative: make anonymous class a normal private inner class

```
Futures.addCallback( tx.submit(), new ToasterInitCallback() );

...

private class ToasterInitCallback implements FutureCallback<void> {

    @Override
    public void onSuccess(final Void result) {
       LOG.info("initToasterOperational: transaction succeeded");
    }
    @Override
    public void onFailure(final Throwable t) {
        LOG.error("initToasterOperational: transaction failed");
    }

}
```

RPCs

Defining RPCs in YANG

Defining RPCs in YANG

Toast RPC definitions

- In **toaster-api** project
- **make-toast, cancel-toast,** and **restock-toaster:** Defined as ‘rpc’ in YANG definition in our YANG mod el file in *toaster-api*
- **input { ... }:** Define inputs to the RPC calls in YANG

Toast RPC implementations

- In **toaster-impl** project
- **makeToast(...), cancelToast(),** and **restockToaster(...):** Methods in your ‘ToastImpl’ class
- **inputs:** auto-generated classes, e.g. ‘MakeToastInput’

```
rpc make-toast {
    input {
        leaf toasterDoneness {
            type uint32 {
                range "1 .. 10";
            }
            default '5';
        }
        leaf toasterToastType {
            type identityref {
                base toast:toast-type;
            }
            default 'wheat-bread';
        }
    }
}  // rpc make-toast

rpc cancel-toast {
}  // rpc cancel-toast

rpc restock-toaster {
    input {
        leaf amountOfBreadToStock {
            type uint32;
        }
    }
}  // rpc restock-toaster
```

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Defining RPCs in YANG

Tasks for implementing RPCs

- In **ToasterImpl** class, must *implement* auto-generated **ToasterService**

```
public class ToasterImpl implements ..., ToasterService, ... {
```

- **Register:** Must register our Toaster Service class with RPC registry

```
@Override
public void onSessionInitiated( ProviderContext session ) {

    // Register the RPC Service
    rpcReg = session.addRpcImplementation( ToasterService.class, this );

}
```

- **Methods:** Must implement our Toaster Service methods, e.g. **makeToast**

```
@Override
public Future<RpcResult<Void>> makeToast( final MakeToastInput input ) {
    LOG.info( "makeToast: {}", input );
    return Futures.immediateFuture( RpcResultBuilder.<Void> success().build() );
}
```

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About These RPC Implementations...

Framework complete

- We have created model objects in our YANG definition
- We have implemented methods for each RPC in our model definition
- **However:** Our RPC methods don't actually do anything yet, other than LOG a message and immediately return success to the caller. See below:

```
@Override
public Future<RpcResult<Void>> makeToast( final MakeToastInput input ) {

    LOG.info( "makeToast: {}", input );
    return Futures.immediateFuture( RpcResultBuilder.<Void> success().build() );

}
```

Putting it all Together

Atomic Variables

• **Concurrency:** Required for concurrency in modern systems with multiple processors, multiple cores, multiple independent caches

• **Lock-free:** Protection for single variable atomic operations without requiring explicit locking and synchronization functions

• **Replace '++', '--':** Allows for atomic increments using 'incrementAndGet', 'addAndGet', 'getAndIncrement', 'compareAndSet', etc. operations

```
private final AtomicLong amountOfBreadInStock = new AtomicLong( 100 );
private final AtomicLong toastsMade           = new AtomicLong( 0 );
...

private class MakeToastTask implements Callable<Void> {
    ...
    // Increment number of toasts made, decrement bread left in stock
    toastsMade.incrementAndGet();
    amountOfBreadInStock.getAndDecrement();
    ....
}
```

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Completing RPC Implementations (simplified version)

Process to get current toaster status, and create task to make toast

- **Read Toaster data:**

```
final ReadWriteTransaction tx = dataService.newReadWriteTransaction();

ListenableFuture<Optional<Toaster>> readFuture =
                      tx.read( LogicalDatastoreType.OPERATIONAL, TOASTER_IID );

final ListenableFuture<Void> commitFuture =
                  Futures.transform( readFuture, new ReadToasterDataFunction() );
```

- **Create task to make toast:**

```
Futures.addCallback( commitFuture, new MakeToastCallbackFunction() );
```

- **Return *futureResult*:**

```
futureResult.set( RpcResultBuilder.<Void>success().build() );
```

Notifications

- **Save notification service on session initiation**

```
private NotificationProviderService notificationService;

public void onSessionInitiated( ProviderContext session ) {
   ...
   this.notificationService =
                     session.getSALService( NotificationProviderService.class );
   ...
}
```

- **Send notification using service**

```
if( outOfBread() ) {

   notificationService.publish( new ToasterOutOfBreadBuilder().build() );

}
```

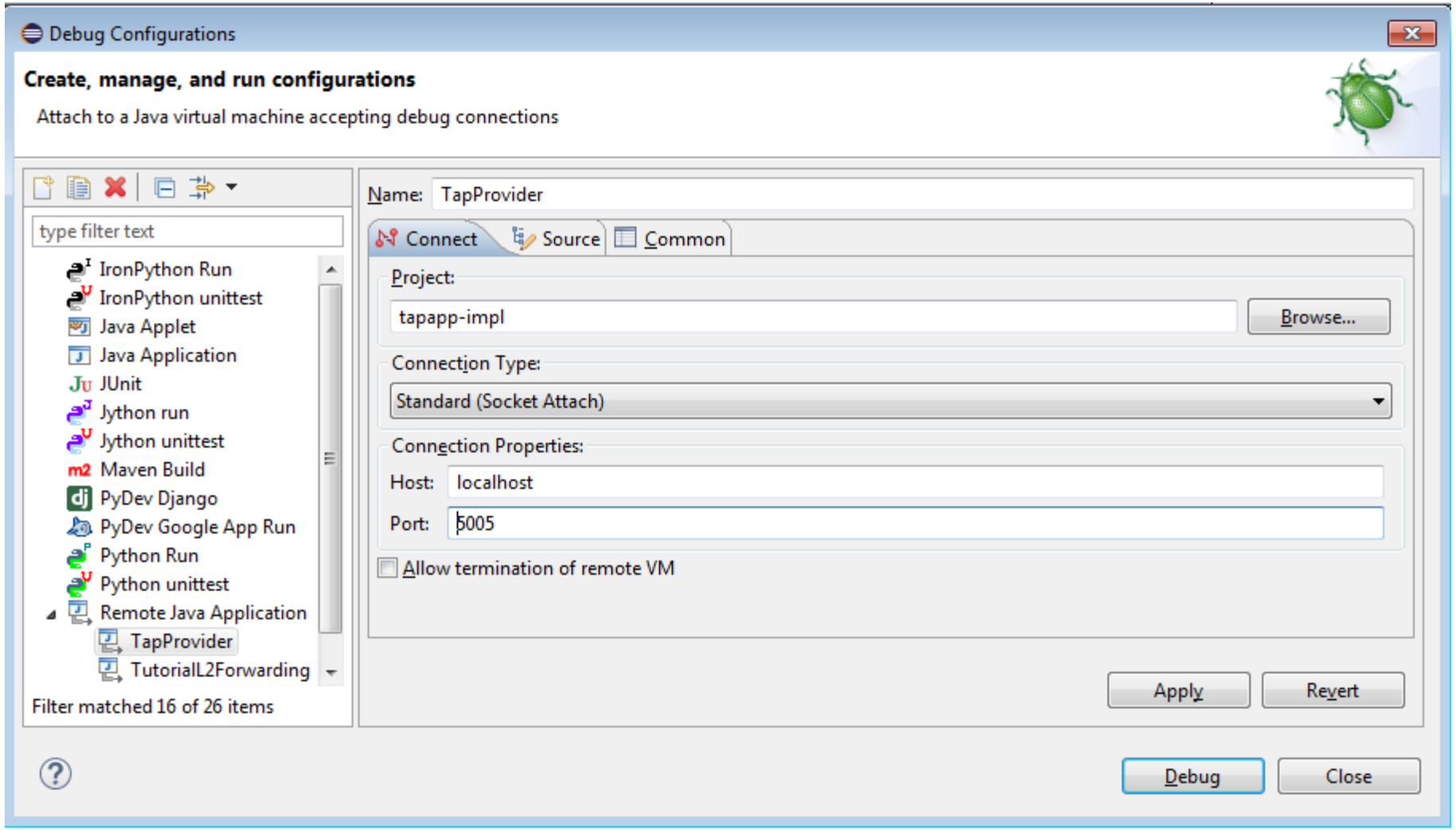
Debug & Release

Debug

%user-root%>%karaf_home%/bin/karaf -debug

%user-root%>%karaf_home%/bin/karaf .bat -debug

Debug



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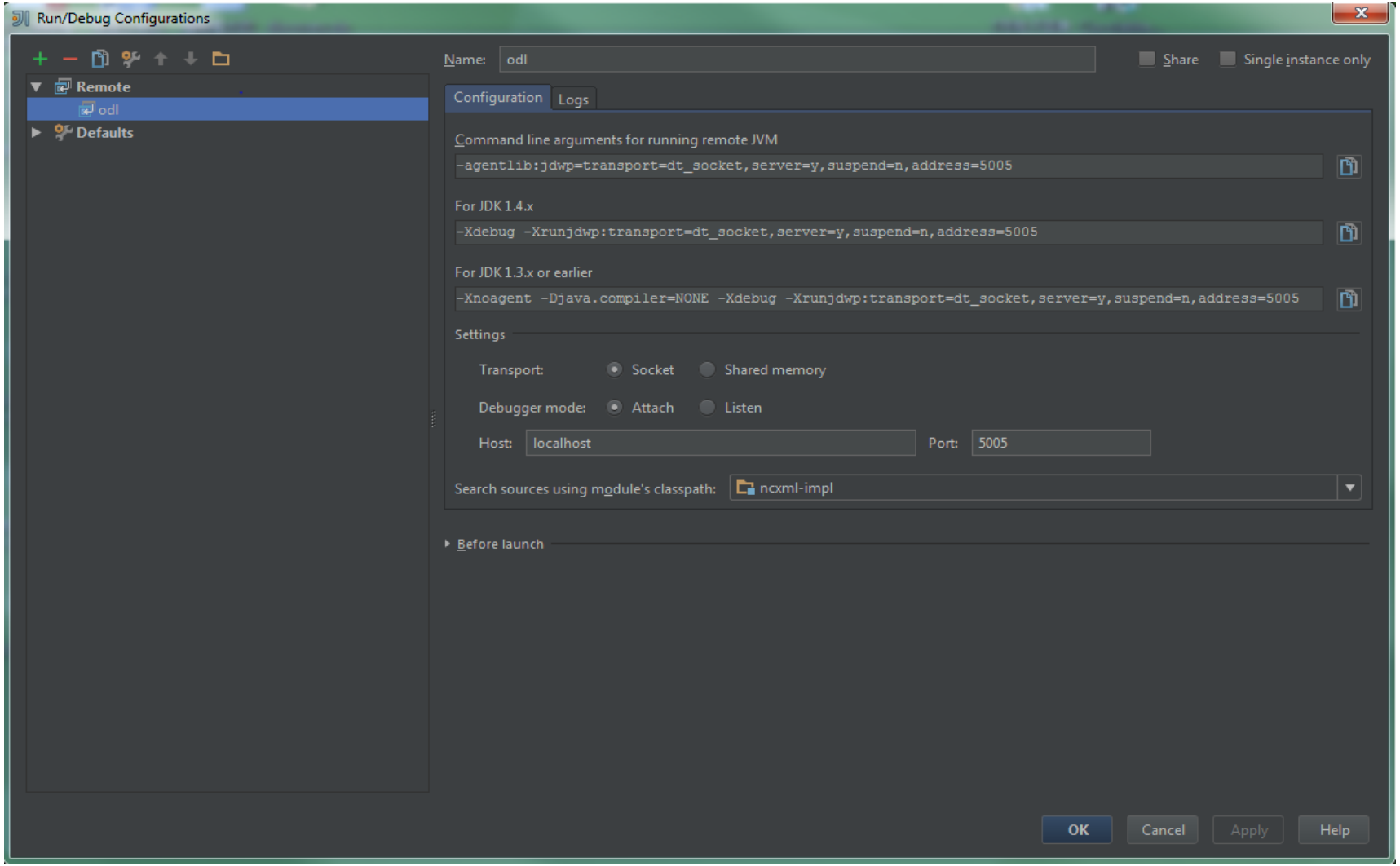
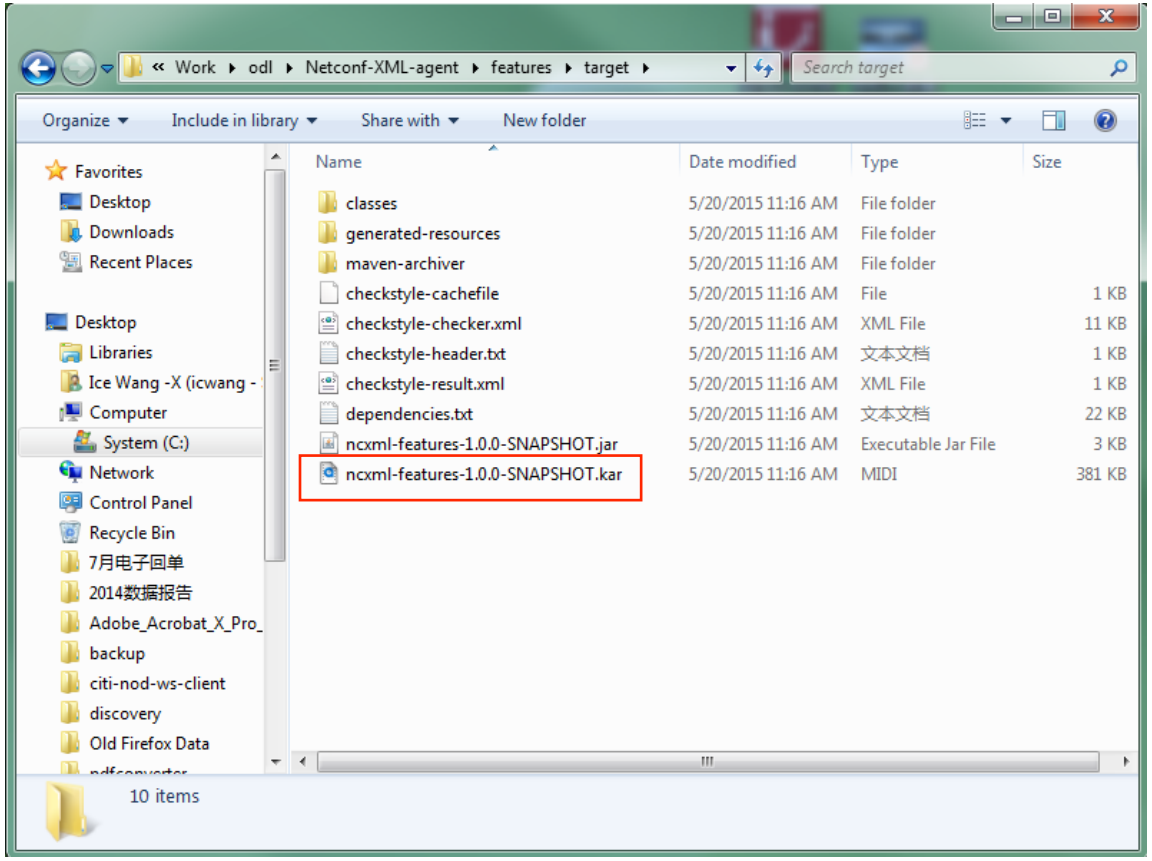
Debug



OPEN DAYLIGHT

Release



1. Put xxxx.kar into karaf\target \assembly\deploy

2. In karaf console, use command line

   feature: install file:%file_path%

OPEN DAYLIGHT

Thank You