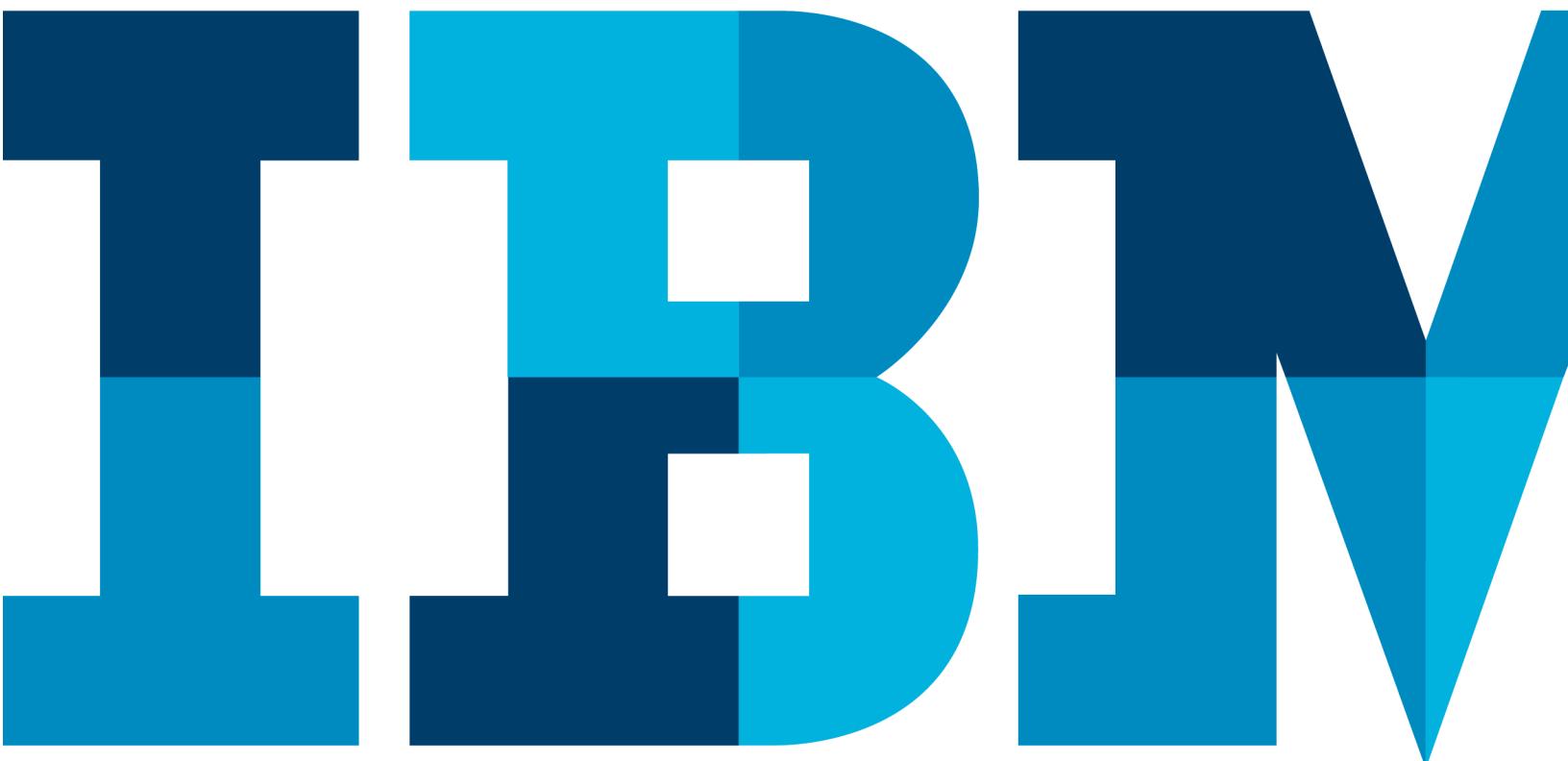


IBM Blockchain Hands-On

Vehicle Lifecycle Lab

Lab One



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Introduction to the Vehicle Lifecycle Lab

This lab allows you to experience a blockchain solution from the point of view of a set of end-users, and in doing so learn about key blockchain concepts. It is not meant to be a technical introduction to blockchain, but will instead focus on the properties of the business network and value that blockchain brings.

The use-case we will work through is one that demonstrates the **lifecycle of a new car**, from the manufacturing and purchasing through to delivery and insurance. It is a good blockchain use-case because there is a defined business network and an identifiable need for trust between the participants of the network.

In this lab, you will be playing the role of the four personas who use the vehicle lifecycle system:

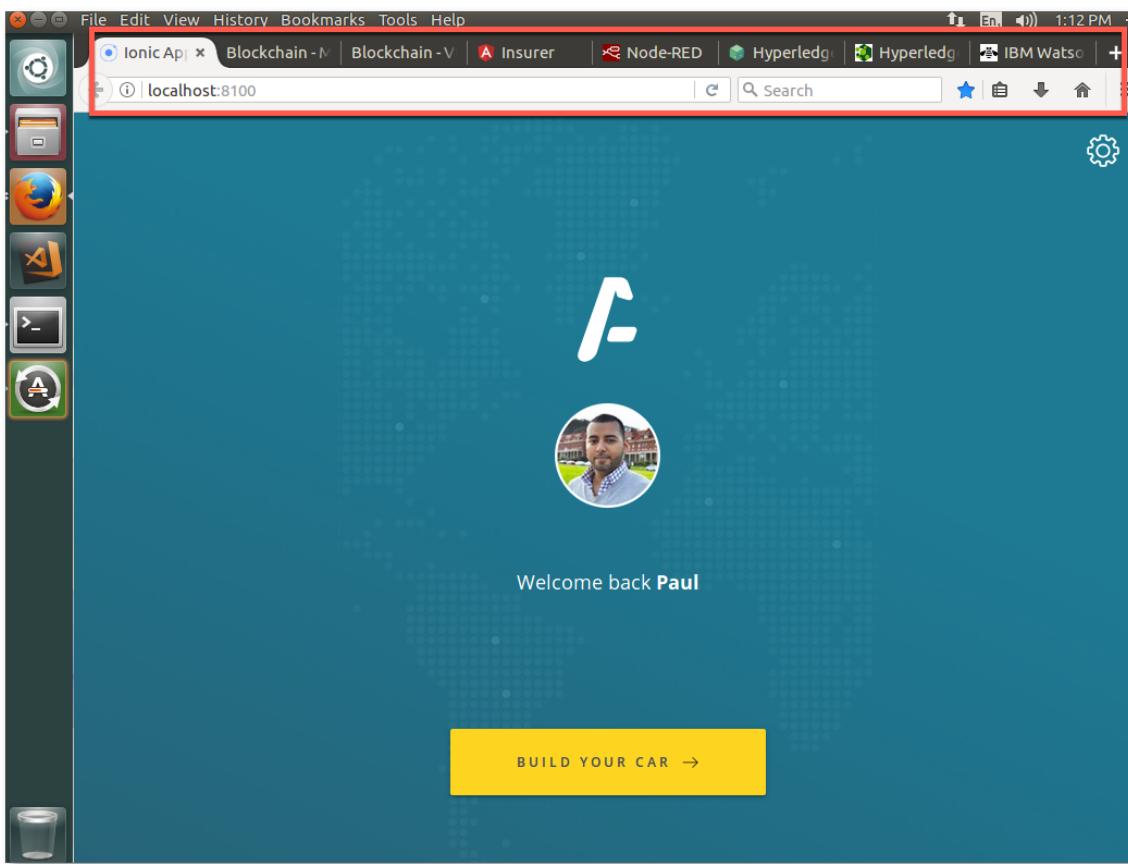
- *Paul* - the buyer/owner of a car
- *Mike* - an employee for the car manufacturer ("Arium")
- *Debbie* - an administrator for the regulator called the Vehicle & Drivers Authority (VDA)
- *Tommen* - an Insurer from an insurance company called Prince

These personas together work on ordering, building, transferring ownership of a vehicle while keeping all the other parties in the network updated and building the trust between them to allow them to work together efficiently.

In this lab, each user's application will be represented by a separate tab in our web browser; of course, in a real blockchain network each user will be running on different systems in different locations, although all connecting in to the same (but distributed) blockchain network.

Start here. Instructions are always shown on numbered lines.

1. If it is not already running, start the virtual machine for the lab. The instructor will tell you how to do this if you are unsure.
2. Wait for the image to boot, and for the blockchain application and associated services to start. This happens automatically but might take several minutes. The image is ready to use when the web browser is visible and eight tabs fully loaded, as per the screenshot below.



While the virtual machine is starting, let's recap a few blockchain concepts and introduce the scenario.

The most generally accepted definition of a blockchain is of a ***shared, replicated ledger***.

Ledgers have been around for hundreds of years and are records of what a business has done. They're important systems of record because they describe a business's inputs and outputs and thereby give an indication of its worth. Essentially, they are a log of transactions – a transaction being a change in state of an asset.

The problem with ledgers is that each one is owned by a single business, which means that when one business transacts with another, ledgers can get out of sync. What happens when the transaction I've recorded on my ledger doesn't tally with the transaction you've recorded on your ledger? Disputes inevitably occur which need to be resolved through a reconciliation process. This can be slow and expensive.

By having a ***shared*** ledger it means that all participants of the business network see the same ledger. By ***replicating*** it across the business network, it means that the ledger is not held in any one single place, which would otherwise make it vulnerable to outages and malicious attack.

Consider the business network that surrounds the purchase and ownership of a car. Today, each participant (for example, manufacturer, insurer or regulator) has their own ledger and the processes that allow them to interact with each other varies from company to company, and can be time consuming to complete. Connectivity between participants is typically done point-to-point using a variety of processes – some manual or slow (e.g. sending a letter), and some automated (e.g. file, REST API, B2B messaging). This plethora of processes is expensive to maintain and can be vulnerable to attack.

In this scenario we will replace these disparate ledgers with a single blockchain, and the individual business processes with a single shared business process. By doing this we will make the overall process much quicker and less prone to error.

We will experience the solution through the eyes of four key members of the business network: a private purchaser, the manufacturer, the regulator and the insurer.

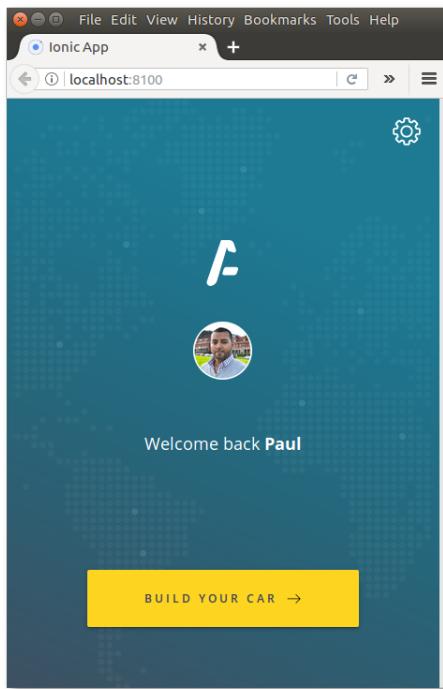
We will start by looking at the ordering process, as experienced by the buyer.

Running the lab

1.1. Ordering the car

3. If it is not already selected, Switch to the “Ionic App” tab on the web browser (running at localhost:8100).

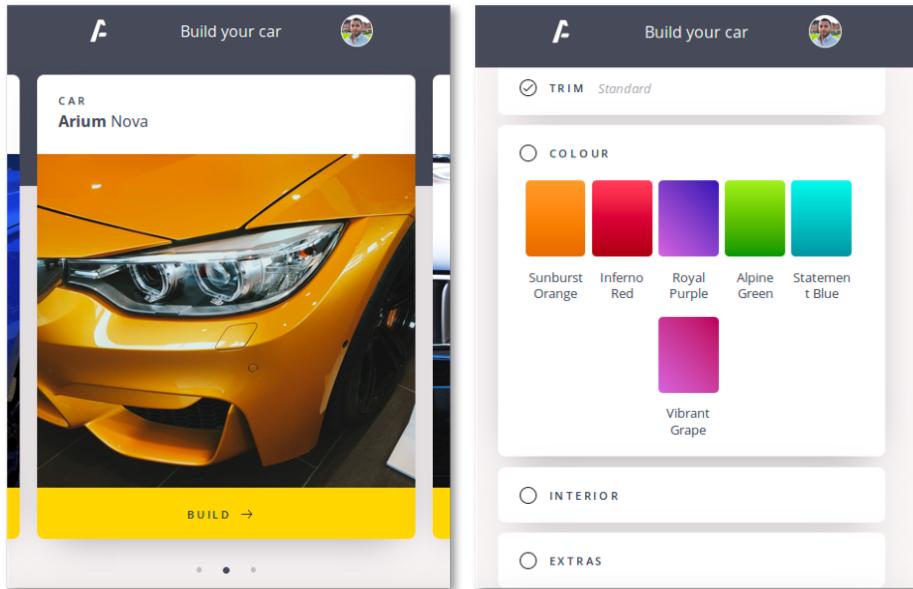
Note that Paul’s web page is intended to be viewed as a mobile app; you might want to ungroup this tab from the others by dragging the tab’s title bar off from the others, and resizing the window to make it easier to view and navigate as a mobile app.



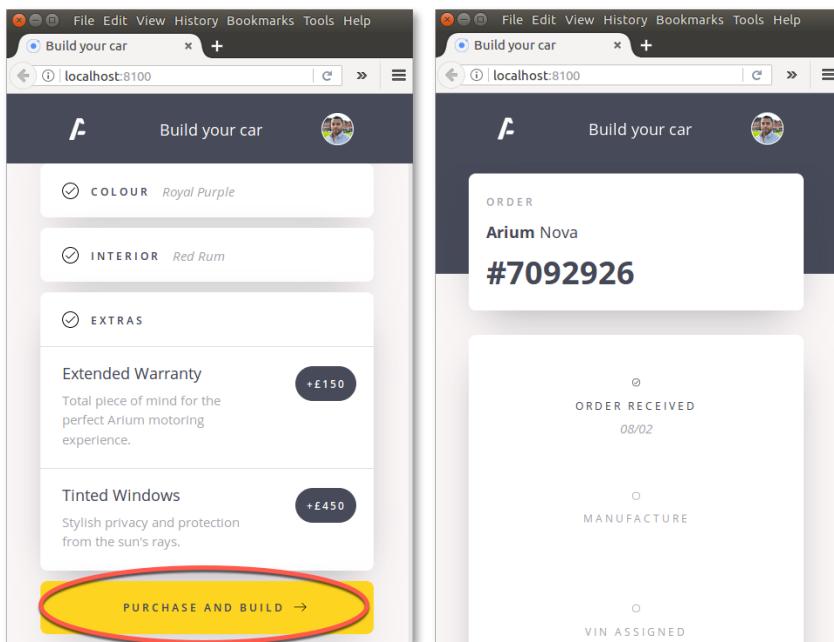
4. In Paul’s app, click ‘Build Your Car’.



- Swipe left and right to decide which car to build, and then decide the options on Paul's car.



- Once you have decided on each of Paul's options, click 'Purchase and Build'.



- Once you place the order, switch to the "Blockchain – VDA" tab (localhost:6001/dashboard).

As you will recall, the VDA is the regulator who requires notification of all transactions that occur within the business network. Debbie, who works for the regulator, has a dashboard running on her PC that shows all transactions as they occur.

You will immediately see the VDA dashboard update itself with the latest transaction.

Blockchain - Manufacturing | Blockchain - VDA | Insurer | Node-RED | Hyperledger Composer | Hyperledger Composer | IBM Watson IoT

localhost:6001/dashboard | Search |

Vehicle & Drivers Authority

REGISTERED VEHICLES: 16 | VIN ASSIGNED: 16 | ASSET ACTIVITY: 22 | SUSPICIOUS VEHICLES: 5 | IN THE LAST WEEK

NEW TRANSACTION | #160 | UpdateOrderStatus

RECENT TRANSACTIONS | LAST 24 HOURS / WEEK / MONTH

Timestamp	Transaction ID	Transaction Type	Transaction Submitter
Feb 8, 2018 2:43:20 PM	a6ad00339e57d8dd6e9f70131e87edede...c17ee0c3415155eb7e9b1f835beebc	UpdateOrderStatus	Arium Vehicles
Feb 8, 2018 2:43:17 PM	e11f4bb6bac7ebee2f5074d658d40d7e25608dbcce9aecc2d3714f28a244cd3b	PlaceOrder	Paul Harris

If you look at the “Recent Transactions” log at the bottom of the page, you will see two new transactions listed: a “PlaceOrder” transaction submitted by Paul Harris, and an “UpdateOrderStatus” acknowledgement from Arium Vehicles, our manufacturer.

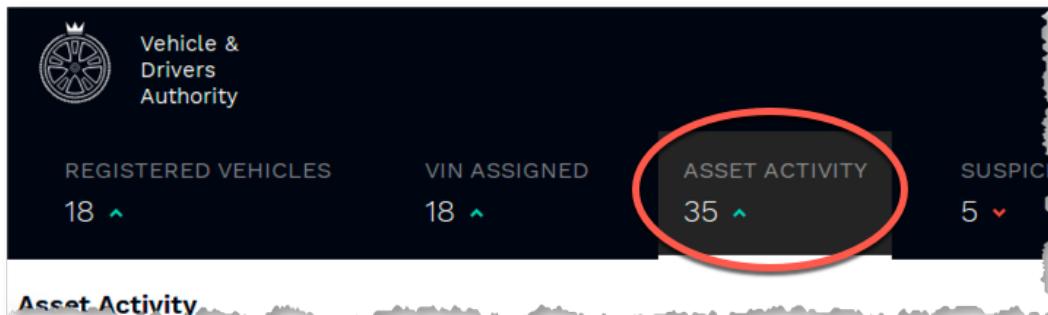
Feb 8, 2018 2:43:20 PM	a6ad00339e57d8dd6e9f70131e87edede...c17ee0c3415155eb7e9b1f835beebc	UpdateOrderStatus	Arium Vehicles
Feb 8, 2018 2:43:17 PM	e11f4bb6bac7ebee2f5074d658d40d7e25608dbcce9aecc2d3714f28a244cd3b	PlaceOrder	Paul Harris

Look in the blue section above this log and you will see those transactions represented graphically as a chain, with the most recent transactions on the right. This is a representation of our blockchain, and the regulator can see everything that is stored on it.



As you will recall, the blockchain is our transaction log which is shared (with appropriate privacy and permissioning) between the participants of our business network. Each block in this chain could potentially actually contain multiple transactions, but here you'll just see each unique transaction inside its own block.

8. Click on 'Asset activity' within the VDA dashboard.



This is an alternative view of the ledger that shows all the transactions that have occurred, and the participants involved.

Asset Activity		LAST 24 HOURS / WEEK / MONTH		
Transaction Type		Transaction Validators		
New Insurance Issued	F431500378a210add59dcda4b09761d47da59b96877401ccf0d7d53465ec06e3	Insurer	+	Vehicle Owner
Vehicle Manufacture (Delivered)	D32491bf58d15bb138d6e15991a87eb67ed4841a94199bcb3d0782e39614506c	Vehicle Owner	+	Vehicle
Vehicle Manufacture (Owner Assigned)	86c68961764ce6acea2c9adb23376241369f1376650aa4bfff078fb0e90f95d1	Manufacturer		
New Usage Record	3d64010b278077097b9bd02c924dc5403a7e3c8e33b1aa5a4d174d5899b451f6	Manufacturer		

1.2. Manufacturing the car

9. Switch to the "Blockchain – Manufacturer" tab (localhost:6002/dashboard).

This is the dashboard that Mike, who works for Arium, uses. He does not have full visibility into the entire blockchain that the regulator requires, but can see the parts of it that pertain to Arium: specifically, he has visibility into all the orders that are coming in so that he can control the manufacturing process.

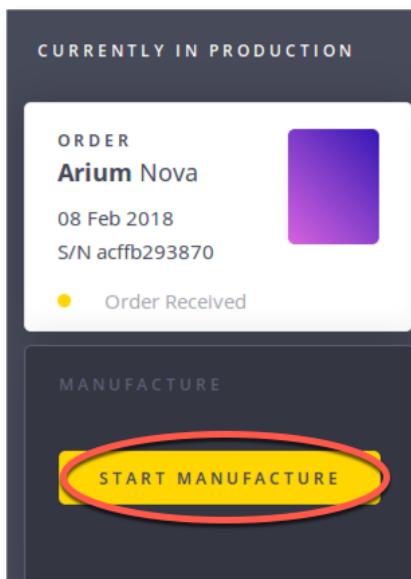
The screenshot shows the Arium Manufacture dashboard with three orders currently in production:

- Order 1: Arium Nova** (Status: Complete)
- Order 2: Arium Thanos** (Status: Complete)
- Order 3: Arium Nova** (Status: Complete)

Below the orders, there is a 'MANUFACTURE' section with a 'START MANUFACTURE' button.

The “Currently in Production” section of this page shows those orders that have been received and the cars that have recently been built. The left-most order in this section will be the car that Paul recently ordered.

- Click Start Manufacture underneath Paul’s order to start the business process to build a car.

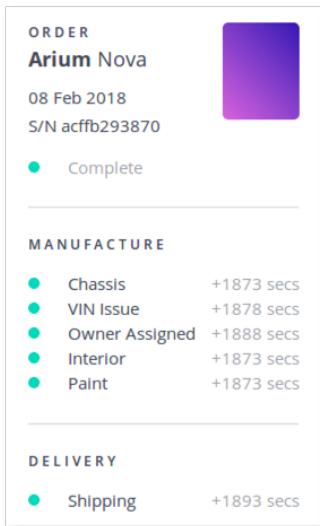


The production process has (of course) been simulated and will take place over the next several seconds; the vehicle will be ‘built’ and blockchain transactions submitted that record status at key milestones of the production process. In a real network, different automated plant systems will trigger these events, which are signed off by the manufacturer, and the issuance of the Vehicle Identification Number might be signed off by the regulator.

11. As the car is being built, switch back to the VDA dashboard to see these key milestones being represented on the unfiltered blockchain.



12. Also note how the Manufacturer's view changes as the vehicle is being built, with icons changing to green as those parts of the process are completed.

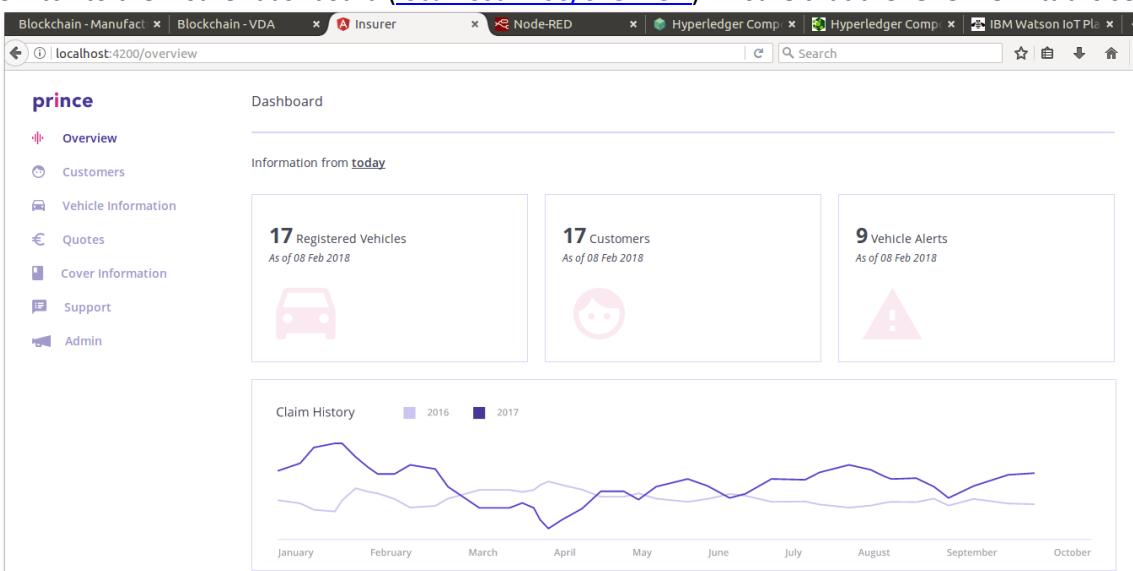


1.3. Insuring the car

As Paul takes ownership of his new car, we will give him the option to insure it. His insurance company offers a discount if he chooses to provide the insurance company with frequent details of the car's location and other things.

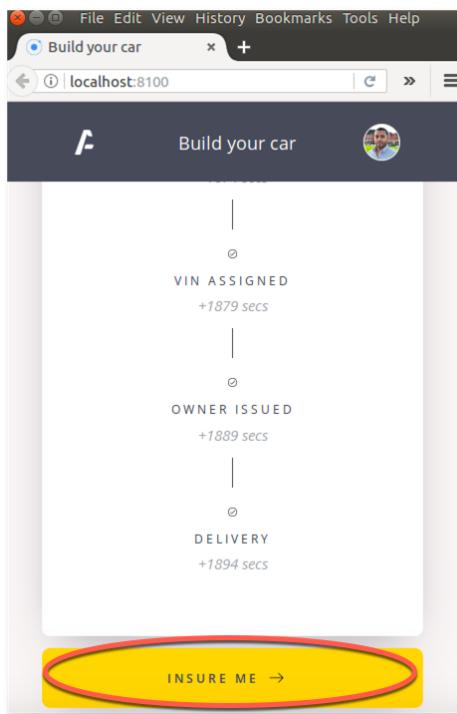
The manufacturer fits the car with a collection of IoT devices, including GPS, air and engine temperature sensors, acceleration information and light information, which can give the insurer information on how the car is being driven, and potentially alert relevant parties if the car is involved in a crash.

13. Switch to the Insurer dashboard (localhost:4200/overview). Ensure that the 'Overview' tab is selected.

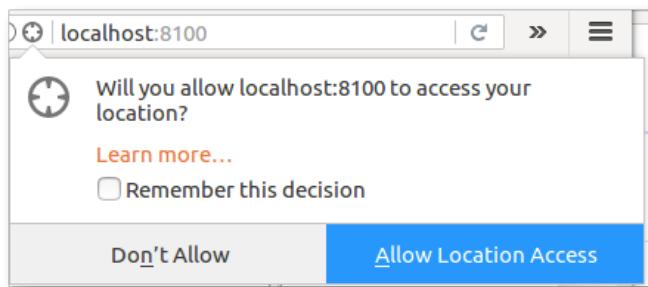


Tommen works for Prince Insurance and this is his dashboard. He requires another subset of information from the blockchain and this view is represented here. He can see information on the cars for which his company is an insurer, and can also approve new polices. (In reality, this latter part can be automated.)

14. Switch back to our car buyer's "Ionic App". After the car has been delivered scroll down to the bottom, and click the "**Insure Me**" button.

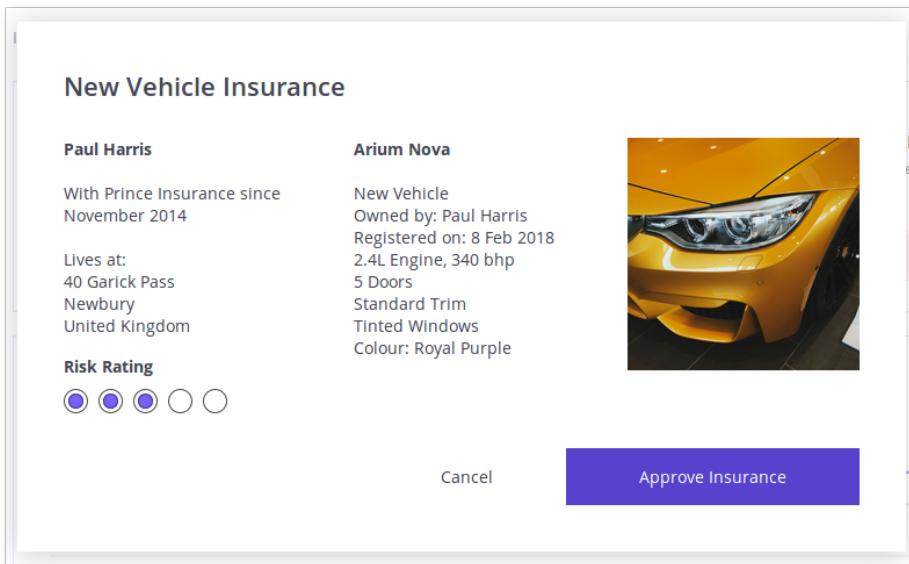


15. Click "**Allow Location Access**" if a popup appears; Paul is willing to share the IoT device's location with the insurance company.



16. Switch back to the "Insurer" view (localhost:4200/overview).

17. Click the "Approve Insurance" button. If the button does not appear, refresh the Insurer view tab.



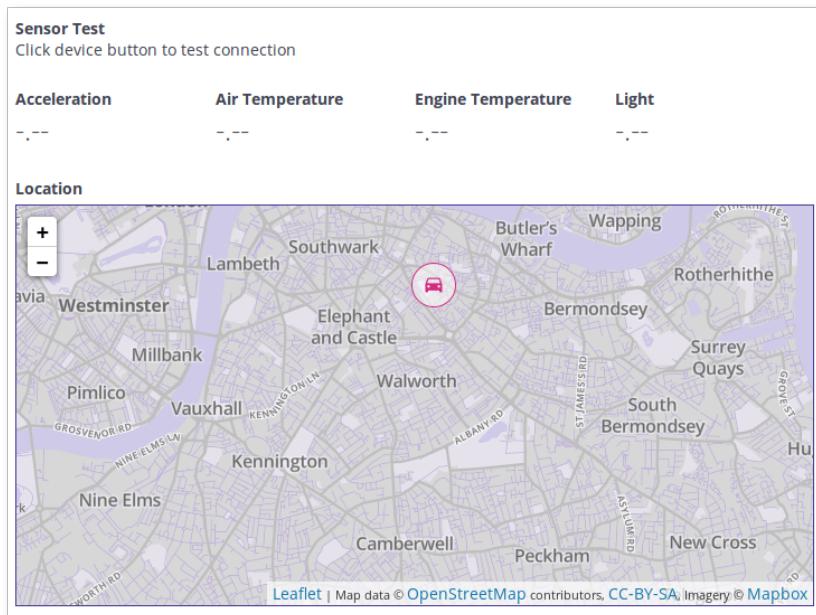
18. Wait for the approval to be logged on the blockchain.

Paul is now insured by the insurance company.

19. Review the 'Customers' tab to see details of Paul's policy.

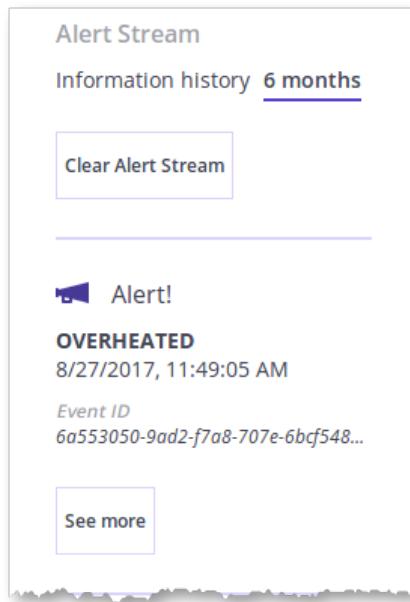
At the top of the page you can see basic details of Paul's policy including his address and car information.

Underneath this is the set of raw readings from the IoT devices attached to Paul's car. This is useful information for debugging; in reality the blockchain is not used to share complete data streams from the IoT sensors as the amount of data is too great and is not relevant to be shared in its entirety.



However, what would be relevant is the analysis of key events in the IoT stream. For example, if the acceleration is shown to be greater than (for example) 2G, this might indicate a crash event that the insurer might care about.

This is shown as a set of alerts on the right hand side of the insurer's customer view:



Without a real sensor tag connected into the application, the information displayed here is either blank or mocked up. In the next section we will inject data into the application using internet of things integration.



It is possible to connect a real sensor tag so that its information is displayed in the Insurer view; we have tested using a Texas Instruments SimpleLink Bluetooth SensorTag. To use this, you need to download the TI SimpleLink Starter app to a nearby mobile device, use it to discover the sensor via Bluetooth, note down the unique address of the tag and enable the “Push to cloud” option to submit the sensor readings so that they can be read by the IBM Watson IoT platform. Then you need to update the “IBM IoTP Test Device” node in the Node-RED flow to monitor the readings from the unique address of the tag from the cloud. Remember to redeploy the Node.RED flow.

Cool Stuff

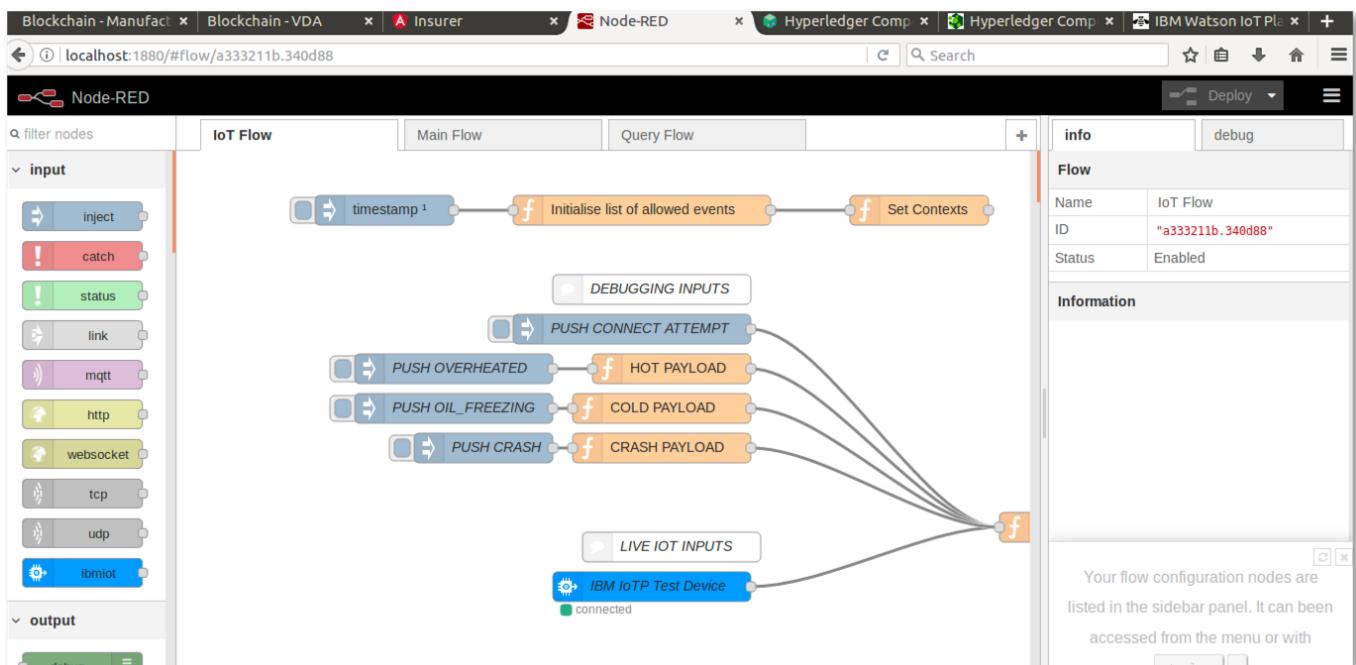
In this section, we're going to look at how the scenario can be enhanced by bringing blockchain together with internet of things and analytics.

1.4. Internet of Things Integration

We will start by looking at how sensor data from the car makes its way into the blockchain. To do this we will use an integration tool called Node-RED. This includes a graphical interface to describe how data flows from input sources (e.g. a sensor) to output sources (e.g. the blockchain).

Node-RED has connectors for sending data to, and receiving data from, a blockchain running Hyperledger Composer. It also has connectors for receiving data from the IBM Watson IoT platform (for sensor tag integration). We can also generate fake sensor data for testing, in the absence of a physical sensor device.

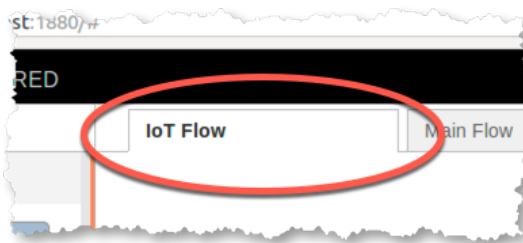
20. Switch to the Node-RED tab (localhost:1880).



The main window shows the flow of how data from devices is mapped to blockchain events. The tabs along the top show the different flows that are deployed. Down the left hand side you can see the available connectors for wiring into the flow. The right hand-side contains the properties of the selected connector and debug information.

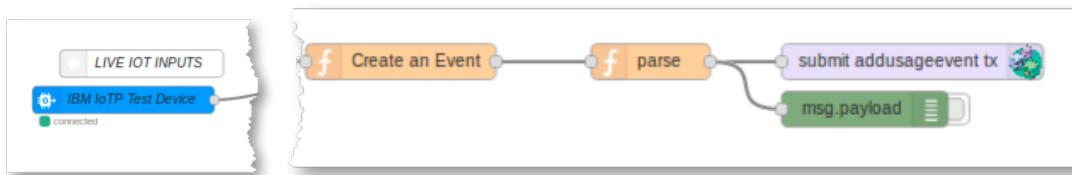
(Note that if you make any changes to the flow, you need to press the “Deploy” button to let them take effect.)

21. Ensure that the “IoT Flow” tab in Node-RED is selected.

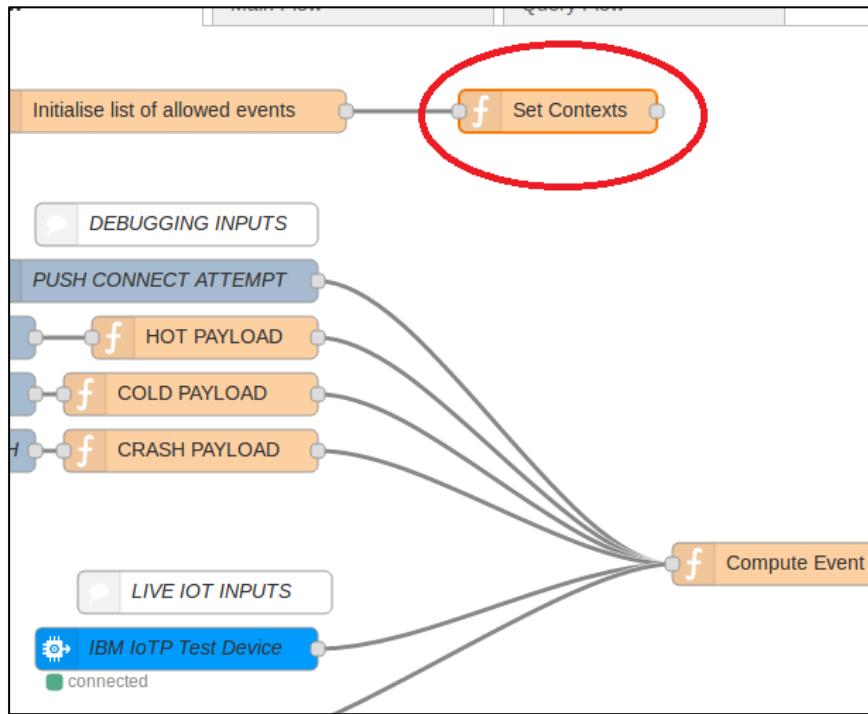


There are some interesting things to note in this flow.

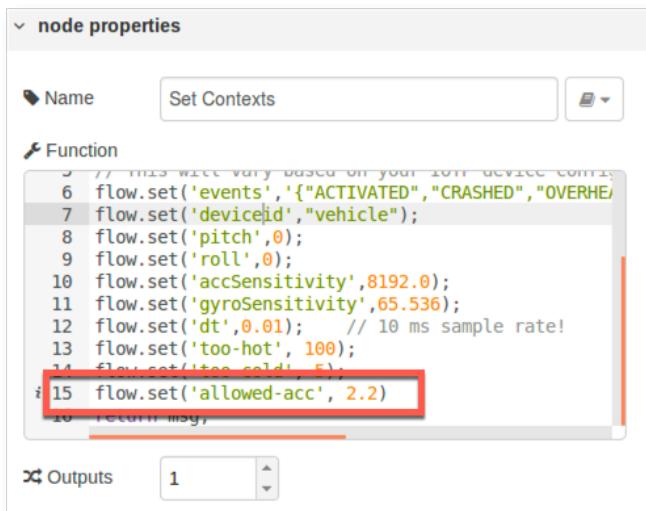
22. Look at the flow path that runs between the “IBM IoTP Test Device” node to the “submit addusageevent tx” flow. This takes readings from a real sensor device and publishes any interesting events to the blockchain.



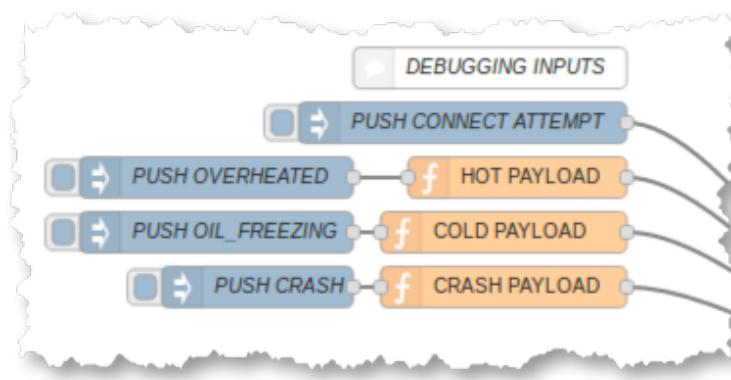
23. Double click the “Set Contexts” node.



This shows the thresholds for sending interesting events to the blockchain. For example, if the acceleration is greater than 2.2G, this causes a crash event to be sent to the blockchain.



24. Look at the set of connectors next to the “DEBUGGING INPUTS” section: PUSH CONNECT ATTEMPT, PUSH OVERHEATED, PUSH OIL FREEZING and PUSH CRASH.



These connectors allow us to simulate an interesting event occurring, in the absence of a real device.

25. Click the rounded square button next to the PUSH CONNECT ATTEMPT connector.



You should see a message saying that data was successfully injected into the flow.



- Switch to the Insurer tab (localhost:4200), and notice under “Sensor Test” that the vehicle sensor is now connected.

Customers // Paul Harris

Paul Harris

Owner of an **Arium Nova**
With Prince Insurance since November 2014
Insured on **3 Nov 2017**

Lives at:
40 Garick Pass
Newbury
United Kingdom

Arium Nova
New Vehicle
Owned by: Paul Harris
Registered on: 3 Nov 2017
2.5L Engine 240bhp
5 Doors
Colour: White

Live Vehicle Information

Sensor Test
Device Connected ✓

Acceleration Air Temperature Engine Temperature Light

- Switch back to the Node-RED tab (localhost:1800), and click the button next to the PUSH OVERHEATED node to send an event to the blockchain which denotes Paul’s engine overheating.



You should again see a “Successfully injected” message.

- In the Insurer view you should see an alert that reveals this event to the insurer.

Alert!

OVERHEATED
8/27/2017, 11:49:05 AM

Event ID
6a553050-9ad2-f7a8-707e-6bcf548...

See more

- Try invoking the other events too (OIL FREEZING, CRASH) to see their effect.

More details on the IBM Watson IoT Platform can be found on a pre-loaded tab in the web browser (<https://i5l9uv.internetofthings.ibmcloud.com/dashboard/#/ibmssoland>).

1.5. Analytics

It is possible to use the information stored on the blockchain to provide insight on aggregate usage patterns to interested authorized parties. This gives the power of data analytics on top of the benefits of a blockchain, as a verifiably clean source of information to analyze.

- Switch back to the Manufacturer view tab ([localhost:6002](http://localhost:6002/reports)) and click the “Reports” link.

The engine overheated events show in this view. These events were captured in the blockchain and the manufacturer role has permission see this type of event. The manufacturer wishes to detect trends in engine overheated failures in order to determine if a factory defect is causing this condition.

Arium Manufacturer

Main

Dashboard

Reports

Goals

Groups

Production

Events

Control Panel

Access

Alerts

Delivery

POST-MANUFACTURE FAILURES

FAILURE
Arium Thanos
Occurred: 1/8/2018, 11:37:33 AM
S/N 59346502241

FAILURE
OVERHEAT

● Engine Temp.	101.00C	● Air Temp.	24.91C
● Acceleration	1.02G	● Roll	-0.05°
● Pitch	-0.01°	● Light	476.96LUX

INSIGHT
2nd Arium Thanos failure this week due to Overheating
Common Factor
Mileage < 100,000

ACTIONABLE INSIGHTS
More information needed for actionable insights

SEND REPORT TO...

The regulator in this scenario can also run analytics on the transactions on the blockchain to look for suspicious behavior that the smart contract was not designed to prevent from a single invocation.

- In the Vehicle & Driver Authority dashboard ([localhost:6001](http://localhost:6001/dashboard)) click the “Suspicious Vehicles” tab near the top.

The screenshot shows the IBM Blockchain Vehicle & Drivers Authority dashboard. At the top, there are statistics: REGISTERED VEHICLES (18), VIN ASSIGNED (18), ASSET ACTIVITY (35), and SUSPICIOUS VEHICLES (5). A red oval highlights the 'SUSPICIOUS VEHICLES' section. Below this, a grid of seven transaction cards is displayed, each with an ID, Transaction ID, and a truncated transaction details field.

ID	TRANSACTION ID	TRANSACTION DETAILS
#168	5d38hb9e6n...af...	...
#169	5d38hb9e6n...af...	...
#170	5d38hb9e6n...af...	...
#171	5d38hb9e6n...af...	...
#172	5d38hb9e6n...af...	...
#173	5d38hb9e6n...af...	...

Here we can see that by performing analytics on the blockchain dataset, we have found a number of vehicles with associated suspicious transactions that may warrant further investigation.

32. Click on 'Mileage anomaly' in the list of suspicious vehicles.

The screenshot shows a table titled 'SUSPICIOUS VEHICLES' with a 'LAST 24 HOU' filter. It lists five vehicles with their VIN and a corresponding notification. The 'Morde Putt - Black' entry has a red oval around the 'Mileage anomaly' notification.

Vehicle	VIN	Notification
Ridge Cannon - White	312457645	Suspicious ownership sequence
Ridge Rancher - White	326548754	Uninsured vehicle
Morde Pluto - Green	564215468	Insurance write-off but still active
Morde Putt - Black	6437956437	Mileage anomaly
Ridge Cannon - Silver	65235647	Untaxed vehicle

This shows a list of the transactions that are associated with this anomaly. In this instance, the mileage of the vehicle may not match with insurance records - or has even decreased from previous records.

The screenshot shows a table for the 'Morde Putt - Black' vehicle with VIN 6437956437. It has a 'Mileage anomaly' notification. The table includes columns for Timestamp, Transaction, Car Owner, and Contact Current Owner button.

Morde Putt - Black	6437956437	Mileage anomaly		
Timestamp	Transaction	Car Owner	Contact Current Owner	X
Nov 3, 2017 6:27:51 PM	b6c71558-0873-335c-635e-adcf32115b17	Anastasia		

Under the Hood

In the final section of the lab, we will briefly consider how the scenario was put together. If you wish to find out more about the tools used to create this application, consider completing a follow-on lab; ask the instructor for details.

1.6. Modelling the Scenario

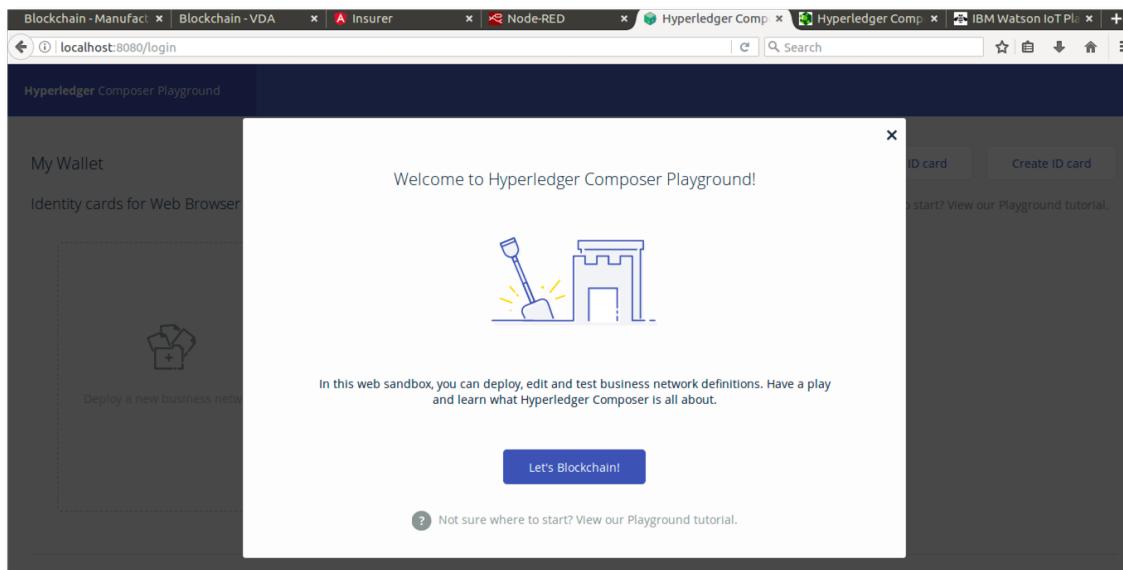
All blockchain use-cases can be described in terms of a set of *assets* (the digital representation of some tangible or intangible object that holds value), *participants* (who wish share information with other participants in a trustworthy way) and *transactions* (which cause the assets to change state).

In our example, the primary asset is the car (obviously), the participants are the owner, manufacturer, regulator and insurer, and as we've seen, there are several transaction types as the car moves through its lifecycle.

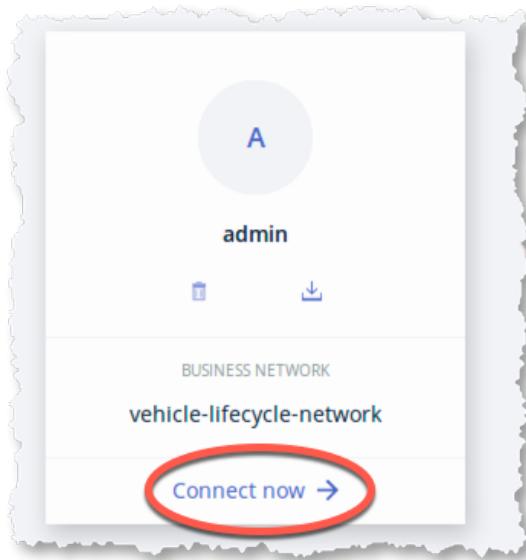
These assets, participants and transactions can be modelled in a Linux Foundation tool called Hyperledger Composer, and leveraged through the IBM Blockchain Platform.

It is useful to develop a model of these concepts as it provides a neat abstraction layer between the business problem being solved and the technical complexities of the underlying blockchain – in much the same way as a compiler shields the programmer from the details of the underlying machine code.

33. Switch to the Hyperledger Composer Playground tab in the web browser (localhost:8080/login).



34. Dismiss the welcome dialog by clicking "Let's Blockchain!".
35. Scroll to the bottom of the "My Wallet" screen to see details of our deployed blockchain network (vehicle-lifecycle-network. Click 'Connect now'.



Once the Playground has connected to the blockchain, you will see details of the vehicle lifecycle network.

Along the top of the screen are two tabs: “Define” which shows the files used to model the network, and “Test” that allows authorized users (an administrator “admin” - by default) to invoke transactions.

36. With the Define tab selected, click the filenames down the left hand side of the screen to view the contents of the files that comprise the model, transaction logic, access control lists and documentation.

```

122 asset Vehicle identified by vin {
123   o String vin
124   o VehicleDetails vehicleDetails
125   o VehicleStatus vehicleStatus
126   --> Person owner optional
127   o String numberPlate optional
128   o String suspiciousMessage optional
129   o VehicleTransferLogEntry[] logEntries optional
130 }

```

We will go into details of what these files do in a follow-on lab.

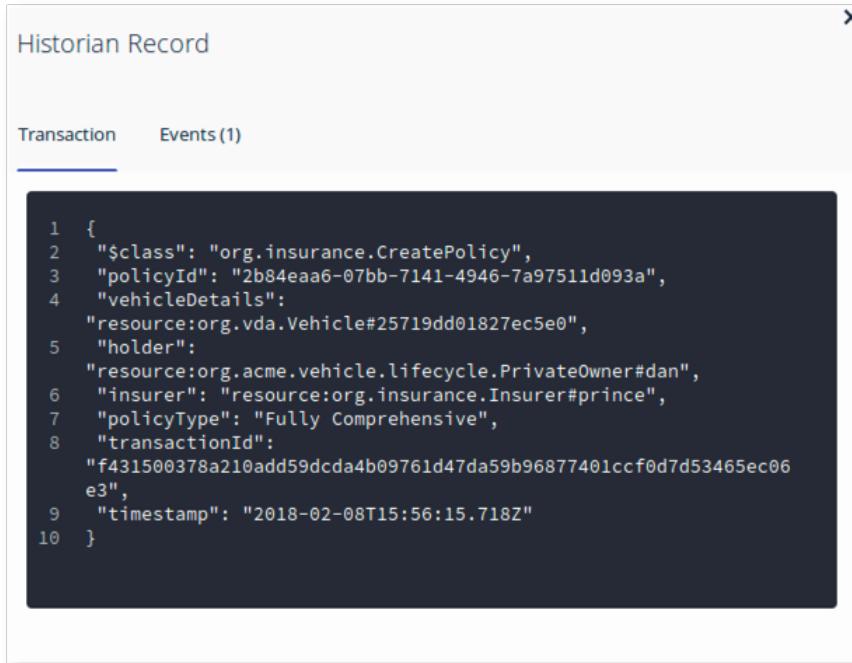
- With the Test tab selected, click the registries down the left hand side of the screen to view the instances of the assets, participants and transactions that have been created, and their current state.

ID	Data
12ff83db-3d5d-35c1-14e1-0c656b3d280a	{ "\$class": "org.insurance.Policy", "policyID": "12ff83db-3d5d-35c1-14e1-0c656b3d280a", "vehicleDetails": "resource:org.vda.Vehicle#156478954", "holder": "resource:org.acme.vehicle.lifecycle.PrivateOwner#dan", "insurer": "resource:org.acme.insurance.Insurer#prince", "notification": "Policy#156478954" }
226de8ed-5925-e9d8-dc13-d46c7f1e5bd2	{ "\$class": "org.insurance.Policy", "policyID": "226de8ed-5925-e9d8-dc13-d46c7f1e5bd2", "vehicleDetails": "resource:org.vda.Vehicle#312748894", "holder": "resource:org.acme.vehicle.lifecycle.PrivateOwner#jake", "insurer": "resource:org.acme.insurance.Insurer#prince", "notification": "Policy#312748894" }
2b84ea6-07bb-7141-4946-7a97511d093a	{ "\$class": "org.insurance.Policy", "policyID": "2b84ea6-07bb-7141-4946-7a97511d093a", "vehicleDetails": "resource:org.vda.Vehicle#25719dd01827ec5e0", "holder": "resource:org.acme.vehicle.lifecycle.PrivateOwner#dan", "insurer": "resource:org.acme.insurance.Insurer#prince", "notification": "Policy#25719dd01827ec5e0" }

- Click 'All Transactions' to view the Transaction Historian. This shows you every transaction that has been recorded on the blockchain that the current user ('admin') has authority to see.

Historian				
ID	Time	Participant ID	Transaction Type	
f431500378a210add59dcda4b09761d47da59...	15:56:15	none	org.insurance.CreatePolicy	view record
d32491bf58d15bb138d6e15991a87eb67ed48...	15:50:10	none	org.acme.vehicle.lifecycle.ma...	view record
86c68961764ce6acea2c9adb23376241369f13...	15:50:05	none	org.acme.vehicle.lifecycle.ma...	view record

- Click on any transaction to view details of it.



The screenshot shows a window titled "Historian Record". At the top, there are two tabs: "Transaction" and "Events (1)". The "Events (1)" tab is selected, indicated by a blue underline. Below the tabs is a dark gray code editor area containing the following JSON-like transaction data:

```
1  {
2    "$class": "org.insurance.CreatePolicy",
3    "policyId": "2b84eaa6-07bb-7141-4946-7a97511d093a",
4    "vehicleDetails":
5      "resource:org.vda.Vehicle#25719dd01827ec5e0",
6      "holder":
7        "resource:org.acme.vehicle.lifecycle.PrivateOwner#dan",
8      "insurer": "resource:org.insurance.Insurer#prince",
9      "policyType": "Fully Comprehensive",
10     "transactionId":
11       "f431500378a210add59dcda4b09761d47da59b96877401ccf0d7d53465ec06
12         e3",
13     "timestamp": "2018-02-08T15:56:15.718Z"
14   }
```

1.7. How the Applications work

While the Playground can be used to test our blockchain scenario, our end-users use mobile apps and dashboards to interact with the running blockchain.

From the files that model this network and implement the transactions, Hyperledger Composer can help this in two ways. Firstly, the models can be used to create skeleton applications that make it easier to develop the end-user applications. Secondly, the models can also be used to generate RESTful APIs that allow client applications and integration middleware to interact with the blockchain.

We will now look at the set of RESTful APIs that have been generated for this scenario.

40. Select the Hyperledger Composer REST server tab (localhost:3000/explorer).

AddUsageEvent : A transaction named AddUsageEvent
 ApplicationForVehicleRegistrationCertificate : A transaction named ApplicationForVehicleRegistrationCertificate
 AuctionHouse : A participant named AuctionHouse
 Company : A participant named Company
 CreatePolicy : A transaction named CreatePolicy
 CreateUsageRecord : A transaction named CreateUsageRecord
 Insurer : A participant named Insurer
 Manufacturer : A participant named Manufacturer

This view shows the REST interface that has been generated from the deployed vehicle lifecycle model. End-user applications and integration middleware can invoke these applications by sending HTTP requests that invoke these APIs.

This is how the Node-RED flows interact with the blockchain. Our end-user applications (Paul's mobile app, the VDA view, Insurer dashboard etc.) can also interact in this way, although it is possible for Javascript client applications to instead import (*require*) a Javascript module that interacts the blockchain in a similar way.

41. Review the different APIs available; feel free to try invoking them from the web front end to see what effect it has on the blockchain, on end-user applications and on Playground views. For example... scroll to the bottom of the list, and click on "Vehicle" to expand its available REST calls - then click on "Get /Vehicle".

Request URL
 http://localhost:3000/api/Vehicle

Response Body

```
[  

  {  

    "$class": "org.vda.Vehicle",  

    "vin": "156478954",  

    "vehicleDetails": {  

      "$class": "org.vda.VehicleDetails",  

      "make": "Arium",  

      "modelType": "Nova",  

      "colour": "white",  

      "vin": "156478954"  

    }  

  }  

]
```

Vehicle : An asset named Vehicle

GET /Vehicle

Response Class (Status 200)
 Request was successful

Next Steps

In this lab you have experienced a live blockchain solution through the eyes of four participants of a vehicle network: a buyer/owner, manufacturer, regulator and insurer. A blockchain can be used to great effect in this business network because there is a clear need to share information and value in participants being able to trust the information they see.

Where you go from here is up to you.

If you have a technical background, consider finding out more about the Hyperledger Fabric and Composer technologies and the blockchain development experience.

If you are interested in the potential benefits of blockchain in your business, IBM has a bunch of services that can help. Start by going to www.ibm.com/blockchain.

Important! Be sure to cleanup the hyperledger fabric environment for subsequent labs. Perform the following at the command prompt in the VLD directory:

- a. Open a terminal window right clicking on the terminal icon  on the left-hand navigation pane of the Ubuntu Linux desktop. Select **New Terminal** and a new terminal window will appear.
- b. **cd VLD**
- c. **./stopAll.sh**

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Please Recycle

IBM Blockchain Hands-On

Hyperledger Fabric SDK

Development:

Writing Your First Application

Lab Two

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Overview

The purpose of this lab is to enable you to write your first blockchain application by introducing you to the Hyperledger Fabric SDK. This lab is based on the “fabcar” Hyperledger Fabric sample:

http://hyperledger-fabric.readthedocs.io/en/release-1.3/write_first_app.html

Writing your First Hyperledger Fabric Application

At the most basic level, applications on a blockchain network are what enable users to **query** a ledger (asking for specific records it contains), or to **update** it (adding records to it).

Our application, composed in JavaScript, leverages the Node.js SDK to interact with the network (where our ledger exists). This tutorial will guide you through the three steps involved in writing your first application.

1. Install Samples, Binaries, and Docker Images. While we work on developing real installers for the Hyperledger Fabric binaries, we provide a script that will download and install samples and binaries to your system. We think that you'll find the sample applications installed useful to learn more about the capabilities and operations of Hyperledger Fabric.

2. Starting a test Hyperledger Fabric blockchain network. We need some basic components in our network in order to query and update the ledger. These components – a peer node, ordering node and Certificate Authority – serve as the backbone of our network; we'll also have a CLI container used for a few administrative commands. A single script will launch this test network.

3. Learning the parameters of the sample smart contract our app will use. Our smart contracts contain various functions that allow us to interact with the ledger in different ways. For example, we can read data holistically or on a more granular level.

4. Developing the application to be able to query and update records. We provide two sample applications – one for querying the ledger and another for updating it. Our apps will use the SDK APIs to interact with the network and ultimately call these functions.

After completing this tutorial, you should have a basic understanding of how an application, using the Hyperledger Fabric SDK for Node.js, is programmed in conjunction with a smart contract to interact with the ledger on a Hyperledger Fabric network.

1.1. Install Samples, Binaries, and Docker Images

- 1 Start a terminal
- 2 cd ~
- 3 Your instructor has already performed this step. However for future reference, you can enter the following command to pull down binaries, docker images, and samples. You do not need to enter the command below as this has already been performed for you on the VMWare image used for these labs. If for some reason, you do not have a **/home/blockchain/fabric-samples** directory, then, issue the command below to pull down the samples.

```
curl -sSL http://bit.ly/2ysboFE | bash -s 1.3.0
```

- 4 cd ~/fabric-samples/first-network
- 5 Issue the following command to shutdown any existing blockchain networks. Answer 'Y' to the Continue prompt.

```
./byfn.sh down
```

- 6 Issue the following command to kill any active or stale containers:

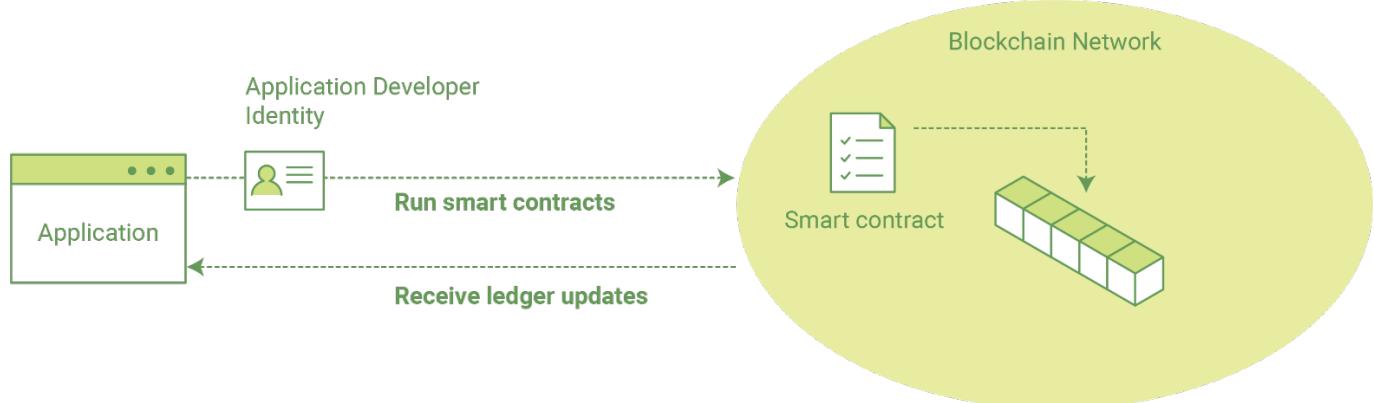
```
docker rm -f $(docker ps -aq)
```

- 7 Issue the following command to clear any cached networks. Answer 'Y' to the Continue prompt.

```
docker network prune
```

1.2. Start the Test Network

- 1 Start a terminal
 - 2 cd ~/fabric-samples/fabcar/
 - 3 Issue the following command which can take a minute or so to complete. The 'node' parameter will start the Node.js chaincode container vs. the Go chaincode container.
- ```
./startFabric.sh node
```
- 4 For the sake of brevity, we won't delve into the details of what's happening with this command. Here's a quick synopsis:
    - launches a peer node, ordering node, Certificate Authority and CLI container
    - creates a channel and joins the peer to the channel
    - installs smart contract (i.e. chaincode) onto the peer's file system and instantiates said chaincode on the channel; instantiate starts a chaincode container
    - calls the `initLedger` function to populate the channel ledger with 10 unique cars
  - 5 These operations will typically be done by an organizational or peer admin. The script uses the CLI to execute these commands, however there is support in the SDK as well. Refer to the [Hyperledger Fabric Node SDK repo](#) for example scripts.
  - 6 Issue a “`docker ps`” command to reveal the processes started by the `startFabric.sh` script. You can learn more about the details and mechanics of these operations in the [Building Your First Network](#) section. Here we'll just focus on the application. The following picture provides a simplistic representation of how the application interacts with the Hyperledger Fabric network.



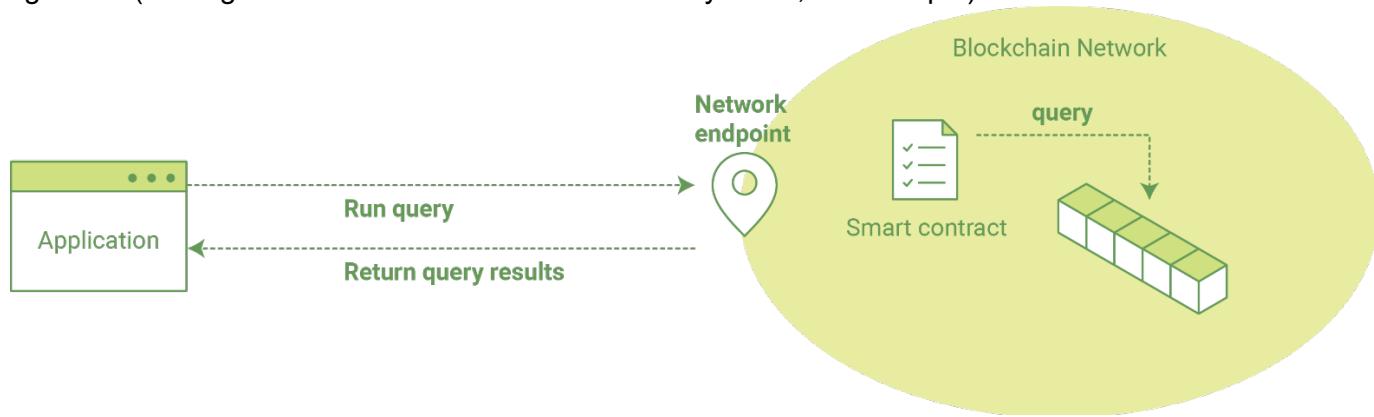
### 1.3. How Applications Interact with the Network

Applications use **APIs** to invoke smart contracts (referred to as “chaincode”). These smart contracts are hosted in the network and identified by name and version. For example, our chaincode container is titled - `dev-peer0.org1.example.com-fabcar-1.0` - where the name is **fabcar**, the version is **1.0** and the peer it is running against is `dev-peer0.org1.example.com`.

APIs are accessible with a software development kit (SDK). For purposes of this exercise, we’ll be using the [Hyperledger Fabric Node SDK](#) though there is also a Java SDK and CLI that can be used to develop applications.

#### Querying the Ledger

Queries are how you read data from the ledger. You can query for the value of a single key, multiple keys, or – if the ledger is written in a rich data storage format like JSON – perform complex searches against it (looking for all assets that contain certain keywords, for example).



As we said earlier, our sample network has an active chaincode container and a ledger that has been primed with 10 different cars. We also have some sample Javascript code - `query.js` - in the **fabcar** directory that can be used to query the ledger for details on the cars.

Before we take a look at how that app works, we need to install the SDK node modules in order for our program to function. From your **fabcar** directory, issue the following:

```
npm install
```

You will issue all subsequent commands from the **fabcar** directory.

- 1 The following two commands involve communication with the Certificate Authority. You may find it useful to view a log of activity with the Certificate Authority. Open a new terminal window and enter the following command.

```
docker logs -f ca.example.com
```

- 2 When we launched our network, an admin user – `admin` – was registered with our Certificate Authority. Now we need to send an enrollment call to the CA server and retrieve the enrollment certificate (`eCert`) for this user. We won’t delve into enrollment details here, but suffice it to say that the SDK and by extension our applications need this cert in order to form a user object for the `admin`. We will then use this `admin` object to subsequently register and enroll a new user. Send the `admin`

enroll call to the CA server.

```
node enrollAdmin.js
```

This program will invoke a certificate signing request (CSR) and ultimately output an eCert and key material into a newly created folder – hfc-key-store – at the root of this project. Our apps will then look to this location when they need to create or load the identity objects for our various users.

- 3 With our newly generated admin eCert, we will now communicate with the CA server once more to register and enroll a new user. This user – user1 – will be the identity we use when querying and updating the ledger. It's important to note here that it is the admin identity that is issuing the registration and enrollment calls for our new user (i.e. this user is acting in the role of a registrar). Send the register and enroll calls for user1:

```
node registerUser.js
```

Similar to the admin enrollment, this program invokes a CSR and outputs the keys and eCert into the hfc-key-store subdirectory. So now we have identity material for two separate users – admin & user1. Time to interact with the ledger...

- 4 Now we can run our javascript programs. First, let's run our `query.js` program to return a listing of all the cars on the ledger. A function that will query all the cars, `queryAllCars`, is pre-loaded in the app, so we can simply run the program as is:

```
node query.js
```

- 5 It should return something like this:

```
Query result count = 1
Response is [{"Key": "CAR0",
 "Record": {"colour": "blue", "make": "Toyota", "model": "Prius", "owner": "Tomoko"}},
 {"Key": "CAR1", "Record": {"colour": "red", "make": "Ford", "model": "Mustang", "owner": "Brad"}},
 {"Key": "CAR2", "Record": {"colour": "green", "make": "Hyundai", "model": "Tucson", "owner": "Jin Soo"}},
 {"Key": "CAR3", "Record": {"colour": "yellow", "make": "Volkswagen", "model": "Passat", "owner": "Max"}},
 {"Key": "CAR4", "Record": {"colour": "black", "make": "Tesla", "model": "S", "owner": "Adriana"}},
 {"Key": "CAR5", "Record": {"colour": "purple", "make": "Peugeot", "model": "205", "owner": "Michel"}},
 {"Key": "CAR6", "Record": {"colour": "white", "make": "Chery", "model": "S22L", "owner": "Aarav"}},
 {"Key": "CAR7", "Record": {"colour": "violet", "make": "Fiat", "model": "Punto", "owner": "Pari"}},
 {"Key": "CAR8", "Record": {"colour": "indigo", "make": "Tata", "model": "Nano", "owner": "Valeria"}},
 {"Key": "CAR9", "Record": {"colour": "brown", "make": "Holden", "model": "Barina", "owner": "Shotaro"}}]
```

These are the 10 cars. A black Tesla Model S owned by Adriana, a red Ford Mustang owned by Brad, a violet Fiat Punto owned by someone named Pari, and so on. The ledger is key/value based and in our implementation the key is CAR0 through CAR9. This will become particularly important in a moment.

- 6 Now let's see what it looks like under the hood (if you'll forgive the pun). Use VSCode to open the `query.js` program with “`code query.js`”.
- 7 The initial section of the application defines certain variables such as channel name and network endpoints:

```
// setup the fabric network
```

```
var channel = fabric_client.newChannel('mychannel');
var peer = fabric_client.newPeer('grpc://localhost:7051');
channel.addPeer(peer);
```

8 This is the chunk where we construct our query:

```
const request = {
 //targets : --- letting this default to the peers assigned to the
 //channel
 chaincodeId: 'fabcar',
 fcn: 'queryAllCars',
 args: ['']
```

We define the `chaincodeId` variable as `fabcar` – allowing us to target this specific chaincode – and then call the `queryAllCars` function defined within that chaincode.

When we issued the `node query.js` command earlier, this specific function was called to query the ledger. However, this isn't the only function that we can pass.

- 9 To take a look at the others, open `fabcar.js` in VSCode with “code `..../chaincode/fabcar/node/fabcar.js`”. You'll see that we have the following functions available to call - `initLedger`, `queryCar`, `queryAllCars`, `createCar` and `changeCarOwner`. Let's take a closer look at the `queryAllCars` function to see how it interacts with the ledger.

```
async queryAllCars(stub, args) {

 let startKey = 'CAR0';
 let endKey = 'CAR999';

 let iterator = await stub.getStateByRange(startKey, endKey);

 let allResults = [];
 while (true) {
 let res = await iterator.next();

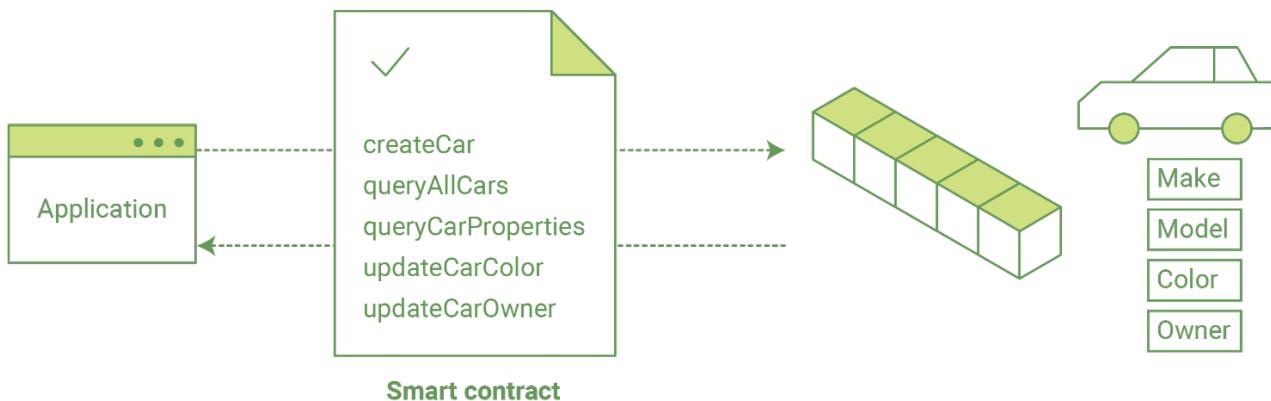
 if (res.value && res.value.value.toString()) {
 let jsonRes = {};
 console.log(res.value.value.toString('utf8'));

 jsonRes.Key = res.value.key;
 try {
 jsonRes.Record =
 JSON.parse(res.value.value.toString('utf8'));
 } catch (err) {
 console.log(err);
 jsonRes.Record = res.value.value.toString('utf8');
 }
 allResults.push(jsonRes);
 }
 if (res.done) {
 console.log('end of data');
 await iterator.close();
 }
 }
}
```

```
 console.info(allResults);
 return Buffer.from(JSON.stringify(allResults));
 }
}
}
```

The function uses the shim interface function `getStateByRange` to return ledger data between the args of `startKey` and `endKey`. Those keys are defined as `CAR0` and `CAR999` respectively. Therefore, we could theoretically create 1,000 cars (assuming the keys are tagged properly) and a `queryAllCars` would reveal every one.

Below is a representation of how an app would call different functions in chaincode.



- 10 We can see our `queryAllCars` function up there, as well as one called `createCar` that will allow us to update the ledger and ultimately append a new block to the chain. But first, let's do another query.
  - 11 Go back to the `query.js` program and edit the request to query a specific car. We'll do this by changing the function from `queryAllCars` to `queryCar` and passing a specific "Key" to the args parameter. Let's use `CAR4` here. So our edited `query.js` program should now contain the following:

```
const request = {
 chaincodeId: 'fabcar',
 fcn: 'queryCar',
 args: ['CAR4']
```

- 12 Save the program and navigate back to your `fabcar` directory. Now run the program again:

```
node query.js
```

- 13 You should see the following:

```
{"colour": "black", "make": "Tesla", "model": "S", "owner": "Adriana"}
```

So we've gone from querying all cars to querying just one, Adriana's black Tesla Model S. Using the `queryCar` function, we can query against any key (e.g. `CAR0`) and get whatever make, model, color, and owner correspond to that car.

Great. Now you should be comfortable with the basic query functions in the chaincode, and the handful of parameters in the query program. Time to update the ledger...

## 1.4. Updating the Ledger

Now that we've done a few ledger queries and changes a bit of code, we're ready to update the ledger. There are a lot of potential updates we could make, but let's just create a new car for starters.

Ledger updates start with an application generating a transaction proposal. Just like query, a request is constructed to identify the channel ID, function, and specific smart contract to target for the transaction. The program then calls the `channel.sendTransactionProposal` API to send the transaction proposal to the peer(s) for endorsement.

The network (i.e. endorsing peer) returns a proposal response, which the application uses to build and sign a transaction request. This request is sent to the ordering service by calling the `channel.sendTransaction` API. The ordering service will bundle the transaction into a block and then "deliver" the block to all peers on a channel for validation. (In our case we have only the single endorsing peer.)

Finally the application uses the `channel.newChannelEventHub` API to connect to the peer's event listener port, and calls `event_hub.registerTxEvent` to register events associated with a specific transaction ID. This API allows the application to know the fate of a transaction (i.e. successfully committed or unsuccessful). Think of it as a notification mechanism.

We don't go into depth here on a transaction's lifecycle. Consult the Transaction Flow documentation for lower level details on how a transaction is ultimately committed to the ledger.

- 1 The goal with our initial invoke is to simply create a new asset (car in this case). We have a separate javascript program - `invoke.js` - that we will use for these transactions. Just like `query.js`, use VSCode to open the file and navigate to the code block where we construct our invocation:

```
var request = {
 //targets: let default to the peer assigned to the client
 chaincodeId: 'fabcar',
 fcn: '',
 args: [''],
 chainId: 'mychannel',
 txId: tx_id
};
```

- 2 You'll see that we can call one of two functions - `createCar` or `changeCarOwner`. Let's create a red Chevy Volt and give it to an owner named Nick. We're up to `CAR9` on our ledger, so we'll use `CAR10` as the identifying key here. The updated code block should look like this:

```
var request = {
 targets: targets,
 chaincodeId: 'fabcar',
 fcn: 'createCar',
 args: ['CAR10', 'Chevy', 'Volt', 'Red', 'Nick'],
 chainId: 'mychannel',
 txId: tx_id
```

- 3 Save it and run the program:

```
node invoke.js
```

- 4 There will be some output in the terminal about Proposal Response and Transaction ID. However, all we're concerned with is this message:

```
The transaction has been committed on peer localhost:7051
```

- 5 The peer emits this event notification, and our application receives it thanks to our `event_hub.registerTxEvent` API. So now if we go back and edit our `query.js` program and call the `queryCar` function against an arg of `CAR10`, we should see the following:

```
Response is {"colour":"Red","make":"Chevy","model":"Volt","owner":"Nick"}
```

- 6 Finally, let's call our last function - `changeCarOwner`. Nick is feeling generous and he wants to give his Chevy Volt to a man named Barry. So, we simply edit `invoke.js` to reflect the following:

```
var request = {
 //targets: let default to the peer assigned to the client
 chaincodeId: 'fabcar'
 fcn: 'changeCarOwner',
 args: ['CAR10', 'Barry'],
 chainId: 'myChannel',
 txId: tx_id
```

- 7 Execute the program again - `node invoke.js` - and then run the query app one final time. We are still querying against `CAR10`, so we should see:

```
Response is {"colour":"Red","make":"Chevy","model":"Volt","owner":"Barry"}
```

## 1.5. Lab Cleanup

- 1 Start a terminal
- 2 `cd ~/fabric-samples/first-network`
- 3 Issue the following command to shutdown any existing blockchain networks. Answer 'Y' to the Continue prompt.

```
./byfn.sh down
```

- 4 Issue the following command to kill any active or stale containers:

```
docker rm -f $(docker ps -aq)
```

- 5 Issue the following command to clear any cached networks. Answer 'Y' to the Continue prompt.

```
docker network prune
```

---

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Please Recycle

# **IBM Blockchain Hands-On**

## **Hyperledger Fabric SDK Development:**

### **Modify Chaincode**

Lab Three

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## Overview

The purpose of this lab is to enable you to modify existing smart contract code invoked by a blockchain application that uses the Hyperledger Fabric SDK.

## Modify Chaincode

At the most basic level, applications on a blockchain network are what enable users to **query** a ledger (asking for specific records it contains), or to **update** it (adding records to it). Chaincode is the business logic that is invoked by the application. Chaincode is the codification of the smart contract.

Our application, composed in JavaScript, leverages the Node.js SDK to interact with the network (where our ledger exists). The chaincode also is composed in Node.js. This tutorial will guide you through the steps involved in modifying the chaincode to add a new method and then using the application to invoke the new chaincode method.

- 1. Perform prerequisite lab cleanup.** Cleanup docker containers and existing networks from the previous lab.
- 2. Modify the sample smart contract our app will use.** Our smart contracts contain various functions that allow us to interact with the ledger in different ways. For example, we can read data holistically or on a more granular level. We will modify the smart contract to add a method to query the transaction history of an asset.
- 3. Starting a test Hyperledger Fabric blockchain network.** We need some basic components in our network in order to query and update the ledger. These components – a peer node, ordering node and Certificate Authority – serve as the backbone of our network; we'll also have a CLI container used for a few administrative commands. A single script will launch this test network.
- 4. Using the application to be able to query and update records.** We provide two sample applications – one for querying the ledger and another for updating it. Our apps will use the SDK APIs to interact with the network and ultimately call these functions. We will modify the query application to invoke the method to query the transaction history of a car.

After completing this tutorial, you should have a basic understanding of how an application, using the Hyperledger Fabric SDK for Node.js is programmed in conjunction with how to modify a smart contract to interact with the ledger on a Hyperledger Fabric network.

### 1.1. Perform prerequisite lab cleanup

- 1 Start a terminal
- 2 cd ~/fabric-samples/first-network
- 3 Issue the following command to shutdown any existing blockchain networks. Answer 'Y' to the Continue prompt.

```
./byfn.sh down
```

- 4 Issue the following command to kill any active or stale containers:

```
docker rm -f $(docker ps -aq)
```

- 5 Issue the following command to clear any cached networks. Answer 'Y' to the Continue prompt.

```
docker network prune
```

- 6 Delete the underlying chaincode image for the fabcar smart contract.

```
docker rmi dev-peer0.org1.example.com-fabcar-1.0-5c906e402ed29f20260ae42283216aa75549c571e2e380f3615826365d8269ba
```

## 1.2. Modify the smart contract to add a car history method

Modify the **fabcar.js** Node.js code in the following steps to add a method to obtain the history of a car. The chaincode API `GetHistoryForKey()` will return history of values for a key. Subsequent steps in this lab will create a new CAR asset and then modify the asset so we have some historical activity for the asset.

- 1 Invoke the VS Code editor for the `fabcar.js` chaincode.

```
code ../chaincode/fabcar/node/fabcar.js
```

- 2 Add the following **getCarHistory** method code snippet after the **queryAllCars** method. Be sure to save your changes in the editor.

```
async getCarHistory(stub, args) {
 console.info('===== START : getCarHistory =====');
 if (args.length != 1) {
 throw new Error('Incorrect number of arguments. Expecting 1');
 }

 let iterator = await stub.getHistoryForKey(args[0]);

 let allResults = [];
 while (true) {
 let res = await iterator.next();

 if (res.value && res.value.value.toString()) {
 let jsonRes = {};
 console.log(res.value.value.toString('utf8'));

 jsonRes.Key = res.value.key;
 try {
 jsonRes.Record = JSON.parse(res.value.value.toString('utf8'));
 } catch (err) {
 console.log(err);
 jsonRes.Record = res.value.value.toString('utf8');
 }
 allResults.push(jsonRes);
 }
 if (res.done) {
 console.log('end of data');
 await iterator.close();
 console.info(allResults);
 return Buffer.from(JSON.stringify(allResults));
 }
 }
}
```

```
}
```

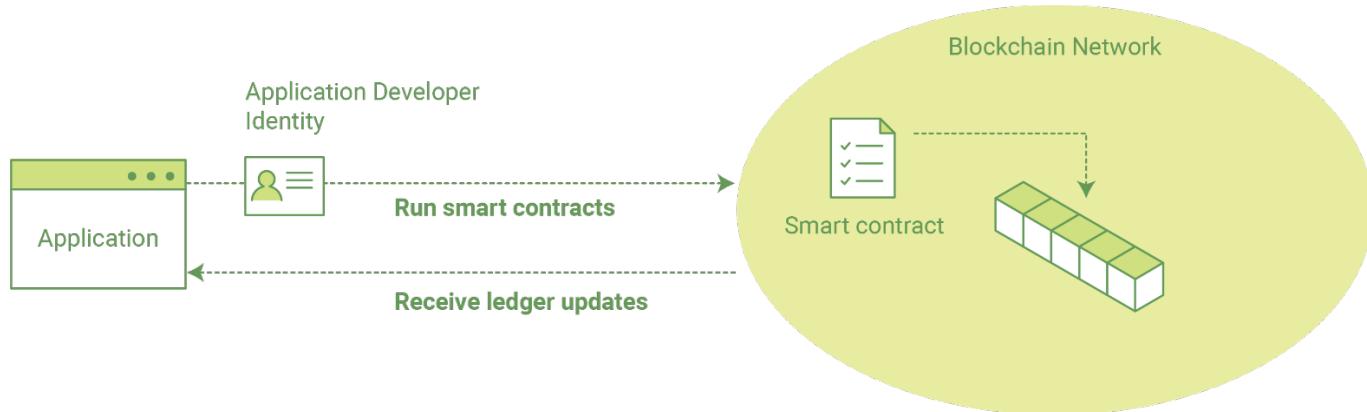
```
}
```

The function uses the shim interface function `getHistoryForKey` to return ledger asset history data for the argument passed to the `getCarHistory` function. `getHistoryForKey` returns a history of key values across time. The History db is enabled in core.yaml file (fabric-samples/config/core.yaml). You can find it enabled in part of the ledger section

```
history:
enableHistoryDatabase - options are true or false
Indicates if the history of key updates should be stored.
All history 'index' will be stored in goleveldb, regardless if using
CouchDB or alternate database for the state.
enableHistoryDatabase: true
```

### 1.3. Start the Test Network

- 1 Start a terminal
- 2 `cd ~/fabric-samples/fabcar/`
- 3 Issue the following command which can take a minute or so to complete. The 'node' parameter will start the Node.js chaincode container vs. the Go chaincode container.  
`./startFabric.sh node`
- 4 Issue the following command to download any required Node.js packages.  
`npm install`
- 5 For the sake of brevity, we won't delve into the details of what's happening with this command. Here's a quick synopsis:
  - launches a peer node, ordering node, Certificate Authority and CLI container
  - creates a channel and joins the peer to the channel
  - installs smart contract (i.e. chaincode) onto the peer's file system and instantiates said chaincode on the channel; instantiate starts a chaincode container
  - calls the `initLedger` function to populate the channel ledger with 10 unique cars
- 6 These operations will typically be done by an organizational or peer admin. The script uses the CLI to execute these commands, however there is support in the SDK as well. Refer to the [Hyperledger Fabric Node SDK repo](#) for example scripts.
- 7 Issue a “`docker ps`” command to reveal the processes started by the `startFabric.sh` script. You can learn more about the details and mechanics of these operations in the [Building Your First Network](#) section. Here we'll just focus on the application. The following picture provides a simplistic representation of how the application interacts with the Hyperledger Fabric network.



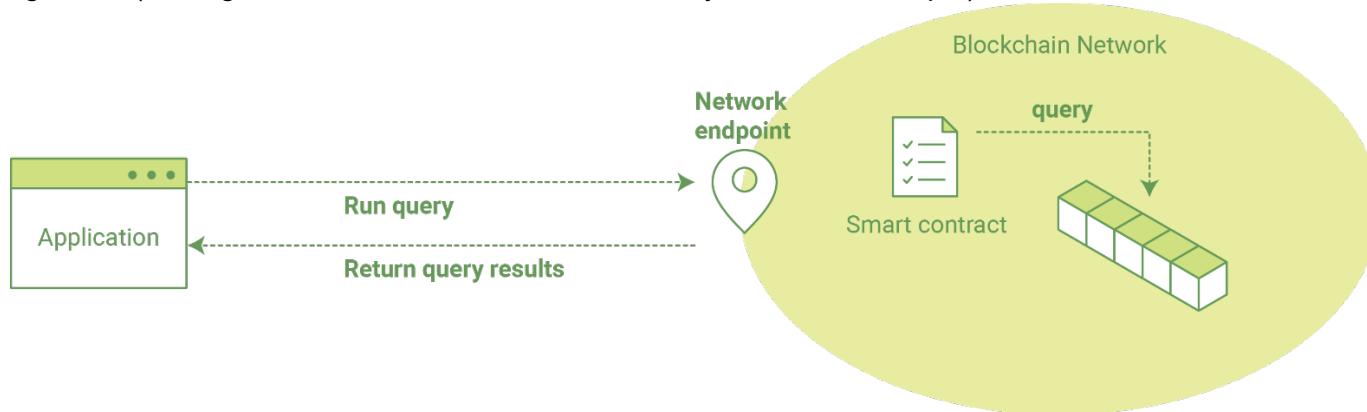
## 1.4. How Applications Interact with the Network

Applications use **APIs** to invoke smart contracts (referred to as “chaincode”). These smart contracts are hosted in the network and identified by name and version. For example, our chaincode container is titled - `dev-peer0.org1.example.com-fabcar-1.0` - where the name is `fabcar`, the version is `1.0` and the peer it is running against is `dev-peer0.org1.example.com`.

APIs are accessible with a software development kit (SDK). For purposes of this exercise, we’ll be using the Hyperledger Fabric Node SDK though there is also a Java SDK and CLI that can be used to develop applications.

### Querying the Ledger

Queries are how you read data from the ledger. You can query for the value of a single key, multiple keys, or – if the ledger is written in a rich data storage format like JSON – perform complex searches against it (looking for all assets that contain certain keywords, for example).



As we said earlier, our sample network has an active chaincode container and a ledger that has been primed with 10 different cars. We also have some sample JavaScript code - `query.js` - in the `fabcar` directory that can be used to query the ledger for details on the cars.

- When we launched our network, an admin user – `admin` – was registered with our Certificate Authority. Now we need to send an enrollment call to the CA server and retrieve the enrollment certificate (`eCert`) for this user. We won’t delve into enrollment details here, but suffice it to say that the SDK and by extension our applications need this cert in order to form a user object for the `admin`. We will then use this `admin` object to subsequently register and enroll a new user. Send the `admin`

enroll call to the CA server.

```
node enrollAdmin.js
```

This program will invoke a certificate signing request (CSR) and ultimately output an eCert and key material into a newly created folder – hfc-key-store – at the root of this project. Our apps will then look to this location when they need to create or load the identity objects for our various users.

- 2 With our newly generated admin eCert, we will now communicate with the CA server once more to register and enroll a new user. This user – user1 – will be the identity we use when querying and updating the ledger. It's important to note here that it is the admin identity that is issuing the registration and enrollment calls for our new user (i.e. this user is acting in the role of a registrar). Send the register and enroll calls for user1:

```
node registerUser.js
```

Similar to the admin enrollment, this program invokes a CSR and outputs the keys and eCert into the hfc-key-store subdirectory. So now we have identity material for two separate users – admin & user1. Time to interact with the ledger...

- 3 Use VSCode to open the `query.js` program with “`code query.js`” and edit the request in `query.js` by entering `node query.js` to look as the follows in order to query all cars. This request was changed in the previous lab. Be sure to save the file.

```
const request = {
 //targets : --- letting this default to the peers assigned to the
 //channel
 chaincodeId: 'fabcar',
 fcn: 'queryAllCars',
 args: ['']
```

- 4 Now we can run our javascript programs. First, let's run our `query.js` program to return a listing of all the cars on the ledger. A function that will query all the cars, `queryAllCars`, is pre-loaded in the app, so we can simply run the program as is:

```
node query.js
```

- 5 It should return something like this:

```
Query result count = 1
Response is [{"Key": "CAR0",
 "Record": {"colour": "blue", "make": "Toyota", "model": "Prius", "owner": "Tomoko"}},
 {"Key": "CAR1", "Record": {"colour": "red", "make": "Ford", "model": "Mustang", "owner": "Brad"}},
 {"Key": "CAR2", "Record": {"colour": "green", "make": "Hyundai", "model": "Tucson", "owner": "Jin Soo"}},
 {"Key": "CAR3", "Record": {"colour": "yellow", "make": "Volkswagen", "model": "Passat", "owner": "Max"}},
 {"Key": "CAR4", "Record": {"colour": "black", "make": "Tesla", "model": "S", "owner": "Adriana"}},
 {"Key": "CAR5", "Record": {"colour": "purple", "make": "Peugeot", "model": "205", "owner": "Michel"}},
 {"Key": "CAR6", "Record": {"colour": "white", "make": "Chery", "model": "S22L", "owner": "Aarav"}},
 {"Key": "CAR7", "Record": {"colour": "violet", "make": "Fiat", "model": "Punto", "owner": "Pari"}},
 {"Key": "CAR8", "Record": {"colour": "indigo", "make": "Tata", "model": "Nano", "owner": "Valeria"}},
 {"Key": "CAR9", "Record": {"colour": "brown", "make": "Holden", "model": "Barina", "owner": "Shotaro"}}]
```

These are the 10 cars. A black Tesla Model S owned by Adriana, a red Ford Mustang owned by Brad, a violet Fiat Punto owned by someone named Pari, and so on. The ledger is key/value based

and in our implementation the key is `CAR0` through `CAR9`. This will become particularly important in a moment.

- 6 To take a look at the other chaincode functions, open `fabcar.js` in VSCode with “code `../chaincode/fabcar/nodefabcar.js`”. You’ll see that we have the following functions available to call - `initLedger`, `queryCar`, `queryAllCars`, `createCar`, `changeCarOwner`, and `getCarHistory`. Let’s take a closer look at the `queryAllCars` function to see how it interacts with the ledger.

```
async queryAllCars(stub, args) {

 let startKey = 'CAR0';
 let endKey = 'CAR999';

 let iterator = await stub.getStateByRange(startKey, endKey);

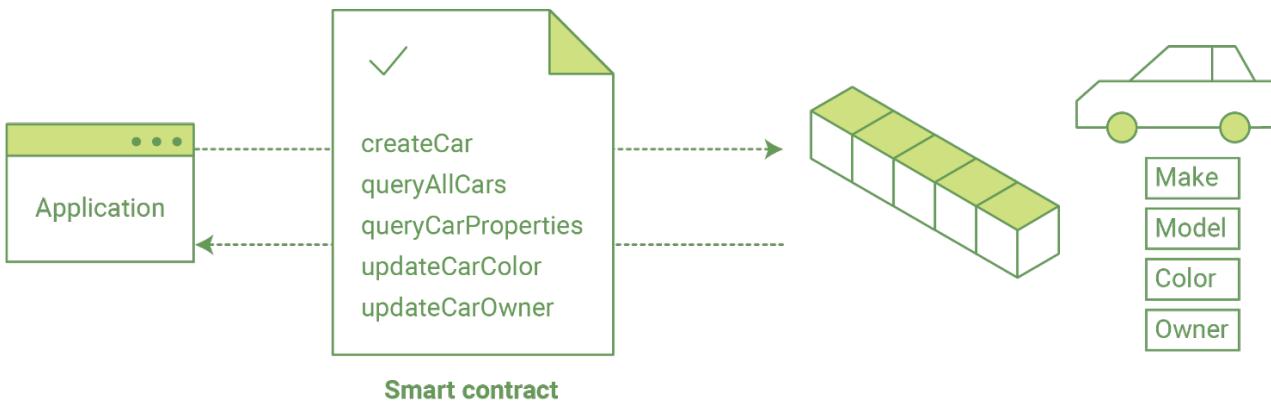
 let allResults = [];
 while (true) {
 let res = await iterator.next();

 if (res.value && res.value.value.toString()) {
 let jsonRes = {};
 console.log(res.value.value.toString('utf8'));

 jsonRes.Key = res.value.key;
 try {
 jsonRes.Record =
 JSON.parse(res.value.value.toString('utf8'));
 } catch (err) {
 console.log(err);
 jsonRes.Record = res.value.value.toString('utf8');
 }
 allResults.push(jsonRes);
 }
 if (res.done) {
 console.log('end of data');
 await iterator.close();
 console.info(allResults);
 return Buffer.from(JSON.stringify(allResults));
 }
 }
}
```

The function uses the shim interface function `getStateByRange` to return ledger data between the args of `startKey` and `endKey`. Those keys are defined as `CAR0` and `CAR999` respectively. Therefore, we could theoretically create 1,000 cars (assuming the keys are tagged properly) and a `queryAllCars` would reveal every one.

Below is a representation of how an app would call different functions in chaincode.



- 7 We can see our `queryAllCars` function up there, as well as one called `createCar` that will allow us to update the ledger and ultimately append a new block to the chain. But first, let's do another query.
- 8 Go back to the `query.js` program and edit the request to query a specific car. We'll do this by changing the function from `queryAllCars` to `queryCar` and passing a specific "Key" to the args parameter. Let's use `CAR4` here. So our edited `query.js` program should now contain the following:

```
const request = {
 chaincodeId: 'fabcar',
 fcn: 'queryCar',
 args: ['CAR4']
```

- 9 Save the program and navigate back to your `fabcar` directory. Now run the program again:

```
node query.js
```

- 10 You should see the following:

```
{"colour": "black", "make": "Tesla", "model": "S", "owner": "Adriana"}
```

So we've gone from querying all cars to querying just one, Adriana's black Tesla Model S. Using the `queryCar` function, we can query against any key (e.g. `CAR0`) and get whatever make, model, color, and owner correspond to that car.

Great. Now you should be comfortable with the basic query functions in the chaincode, and the handful of parameters in the query program. Time to update the ledger...

## 1.5. Updating the Ledger

Now that we've done a few ledger queries and changes a bit of code, we're ready to update the ledger. There are a lot of potential updates we could make, but let's just create a new car for starters.

Ledger updates start with an application generating a transaction proposal. Just like query, a request is constructed to identify the channel ID, function, and specific smart contract to target for the transaction. The program then calls the `channel.sendTransactionProposal` API to send the transaction proposal to the peer(s) for endorsement.

The network (i.e. endorsing peer) returns a proposal response, which the application uses to build and sign a transaction request. This request is sent to the ordering service by calling the `channel.sendTransaction` API. The ordering service will bundle the transaction into a block and then “deliver” the block to all peers on a channel for validation. (In our case we have only the single endorsing peer.)

Finally the application uses the `channel.newChannelEventHub` API to connect to the peer’s event listener port, and calls `event_hub.registerTxEvent` to register events associated with a specific transaction ID. This API allows the application to know the fate of a transaction (i.e. successfully committed or unsuccessful). Think of it as a notification mechanism.

We don’t go into depth here on a transaction’s lifecycle. Consult the Transaction Flow documentation for lower level details on how a transaction is ultimately committed to the ledger.

- 1 The goal with our initial invoke is to simply create a new asset (car in this case). We have a separate javascript program - `invoke.js` - that we will use for these transactions. Just like `query.js`, use VSCode to open the file and navigate to the code block where we construct our invocation:

```
var request = {
 //targets: let default to the peer assigned to the client
 chaincodeId: 'fabcar',
 fcn: '',
 args: [''],
 chainId: 'mychannel',
 txId: tx_id
};
```

- 2 You’ll see that we can call one of two functions - `createCar` or `changeCarOwner`. Let’s create a red Chevy Volt and give it to an owner named Nick. We’re up to `CAR9` on our ledger, so we’ll use `CAR10` as the identifying key here. The updated code block should look like this:

```
var request = {
 chaincodeId: 'fabcar',
 fcn: 'createCar',
 args: ['CAR10', 'Chevy', 'Volt', 'Red', 'Nick'],
 chainId: 'mychannel',
 txId: tx_id
```

- 3 Save it and run the program:

```
node invoke.js
```

- 4 There will be some output in the terminal about Proposal Response and Transaction ID. However, all we’re concerned with is this message:

The transaction has been committed on peer localhost:`7051`

- 5 The peer emits this event notification, and our application receives it thanks to our `event_hub.registerTxEvent` API. So now if we go back and edit our `query.js` program and call the `queryCar` function against an arg of `CAR10`, we should see the following:

```
Response is {"colour":"Red","make":"Chevy","model":"Volt","owner":"Nick"}
```

- 6 Finally, let's change ownership of the car to establish a history for the vehicle - `changeCarOwner`. Nick is feeling generous and he wants to give his Chevy Volt to a man named Barry. So, we simply edit `invoke.js` to reflect the following:

```
var request = {
 //targets: let default to the peer assigned to the client
 chaincodeId: 'fabcar'
 fcn: 'changeCarOwner',
 args: ['CAR10', 'Barry'],
 chainId: 'myChannel',
 txId: tx_id
```

- 7 Execute the program again - `node invoke.js` - and then run the query app one final time. We are still querying against `CAR10`, so we should see:

```
Response is {"colour":"Red","make":"Chevy","model":"Volt","owner":"Barry"}
```

- 8 Finally, go back to the `query.js` program and edit the request to query the history for a specific car. We'll do this by changing the function from `queryCar` to `getCarHistory` and passing a specific "Key" to the args parameter. Let's use CAR10 here. So our edited `query.js` program should now contain the following:

```
const request = {
 chaincodeId: 'fabcar',
 fcn: 'getCarHistory',
 args: ['CAR10']
```

Run `node query.js` to rerun the query once again. This time the results will show the complete history for the CAR10 asset. The history includes an initial record for the asset creation and an additional record for when we modified CAR10 to have an owner of Barry.

```
Response is
[{"Record": {"docType": "car", "make": "Chevy", "model": "Volt", "color": "Red", "owner": "Nick"}, {"Record": {"color": "Red", "docType": "car", "make": "Chevy", "model": "Volt", "owner": "Barry"}}]
```

## 1.6. Lab Cleanup

- 1 Start a terminal and change to the first-network project.

```
cd ~/fabric-samples/first-network
```

- 2 Issue the following command to shutdown any existing blockchain networks. Answer 'Y' to the

Continue prompt.

```
./byfn.sh down
```

- 3 Issue the following command to kill any active or stale containers:

```
docker rm -f $(docker ps -aq)
```

- 4 Issue the following command to clear any cached networks. Answer 'Y' to the Continue prompt.

```
docker network prune
```

- 5 Close VSCode by choosing File->Exit from the VSCode menu bar.

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| Rational        | Redbooks      | Red Brick        | RequisitePro     | System i        |            |
| <i>System z</i> | <i>Tivoli</i> | <i>WebSphere</i> | <i>Workplace</i> | <i>System p</i> |            |

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Please Recycle

# **IBM Blockchain Hands-On**

## **VSCode Extension for IBM Blockchain Platform: Generate, Deploy, Instantiate, and Test Smart Contracts**

Lab Four

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## Overview

The purpose of this lab is to enable you to become familiar with the new VSCode IBM Blockchain Platform extension to generate template smart contracts, deploy to a local Hyperledger Fabric instance, and test the smart contract using a generated test Node.js test module.

## IBM Blockchain Platform Extension Overview

The IBM Blockchain Platform extension has been created to assist users in developing, testing, and deploying smart contracts; including connecting to Hyperledger Fabric environments. The IBM Blockchain Platform extension provides an explorer and the following commands in the table below accessible from the Command Palette, for developing smart contracts quickly:

| Command                              | Description                                                                                                                                                                                        |
|--------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Add Connection                       | Add a Hyperledger Fabric instance connection                                                                                                                                                       |
| Add Identity To Connection           | Add an identity to be used when connecting to a Hyperledger Fabric instance                                                                                                                        |
| Connect To Blockchain                | Connect to a Hyperledger Fabric blockchain using a blockchain connection                                                                                                                           |
| Create Smart Contract Project        | Create a new JavaScript or TypeScript smart contract project                                                                                                                                       |
| Delete Connection                    | Delete a Hyperledger Fabric instance connection                                                                                                                                                    |
| Delete Package                       | Delete a smart contract package                                                                                                                                                                    |
| Edit Connection                      | Edit connection to a blockchain                                                                                                                                                                    |
| Export Package                       | Export an already-packaged smart contract package to use outside VSCode                                                                                                                            |
| Disconnect From Blockchain           | Disconnect from the blockchain you're currently connected to                                                                                                                                       |
| Install Smart Contract               | Install a smart contract package onto a peer                                                                                                                                                       |
| Instantiate / Upgrade Smart Contract | Instantiate / upgrade an installed smart contract package onto a channel<br><i>*Note: This currently doesn't work with IBM Blockchain Platform Starter Plan and Enterprise plan - Coming soon!</i> |
| Package a Smart Contract Project     | Create a new smart contract package from a project in the Explorer                                                                                                                                 |
| Refresh Blockchain Connections       | Refresh the Blockchain Connections view                                                                                                                                                            |
| Refresh Smart Contract Packages      | Refresh the Smart Contract Packages view                                                                                                                                                           |
| Restart Fabric Runtime               | Restart a Hyperledger Fabric instance                                                                                                                                                              |
| Start Fabric Runtime                 | Start a Hyperledger Fabric instance                                                                                                                                                                |
| Teardown Fabric Runtime              | Teardown the local_fabric runtime (hard reset)                                                                                                                                                     |
| Toggle Development Mode              | Toggle the Hyperledger Fabric instance development mode                                                                                                                                            |

This tutorial is an introduction to the new IBM Blockchain Platform extension which is currently under development. The tutorial will guide you through the steps to steps involved in generating a smart contract, installing and instantiating the smart contract, and then unit testing the smart contract. This lab was tested with the .4 version or higher of the extension. Please note: this extension is available for early experimentation. There are many features and improvements to come before the v1.0 release. Please bear this in mind, and if you find something you'd like to see added, let the team know by raising a GitHub issue at

<https://github.com/IBM-Blockchain/blockchain-vscode-extension/issues>

- 1. Starting a local Hyperledger Fabric blockchain instance.** The extension enables to connect to an external Hyperledger Fabric instance or an embedded local Hyperledger Fabric instance. We will connect to the local Hyperledger Fabric instance.
- 2. Use the extension to generate a template smart contract.** We will generate a sample smart contract template.
- 3. Package, deploy, and instantiate the smart contract.** We will package, deploy, and instantiate the smart contract using the extension.
- 4. Test the smart contract.** We will test the smart contract using a generated test module.

After completing this tutorial, you should have a basic understanding on how to use the IBM Blockchain Platform VSCode extension.

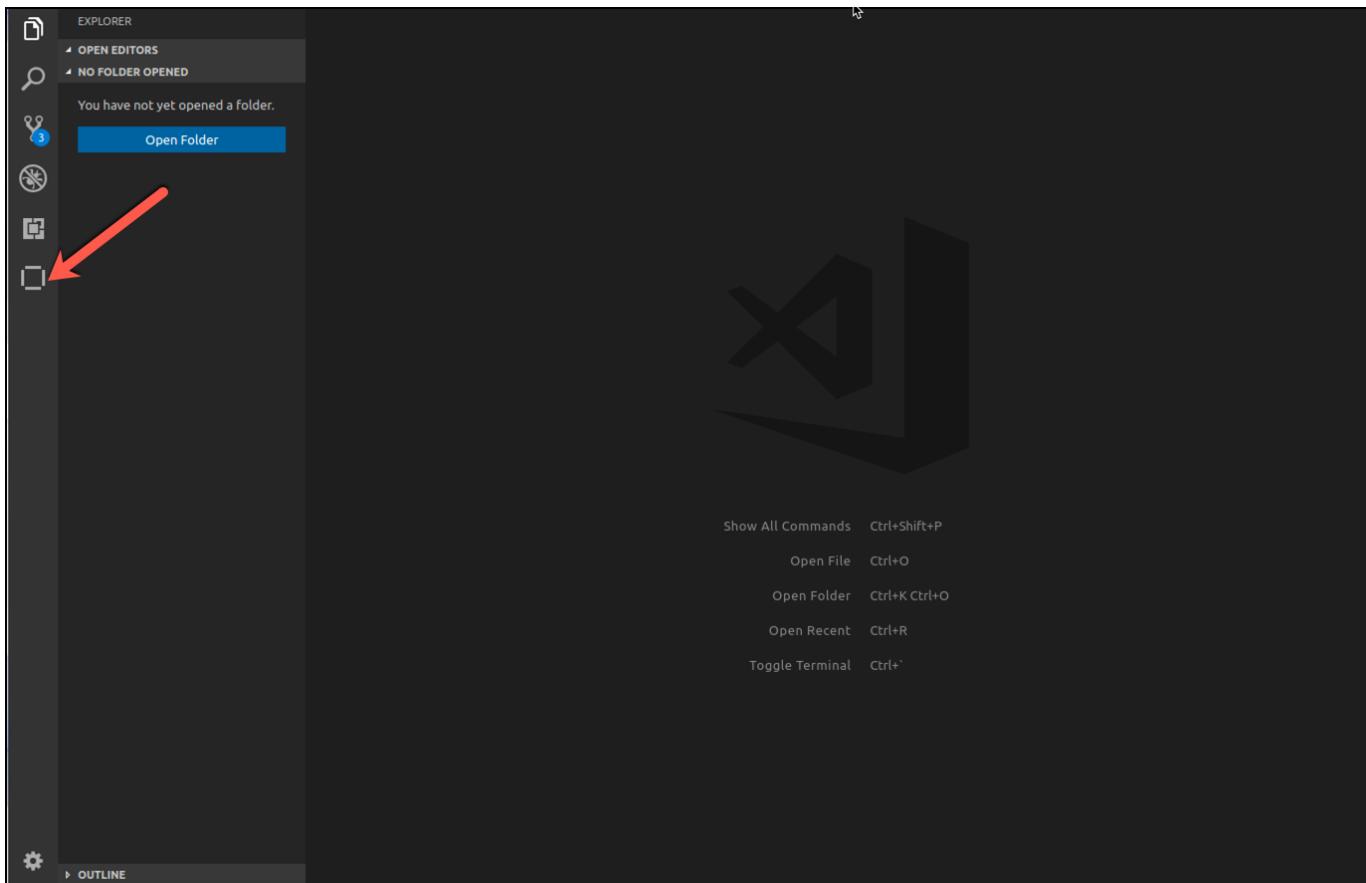
## 1.1. Start a local Hyperledger Fabric instance

In this section you will start and connect to a local Hyperledger Fabric instance that is automatically configured by the IBM Blockchain Platform extension.

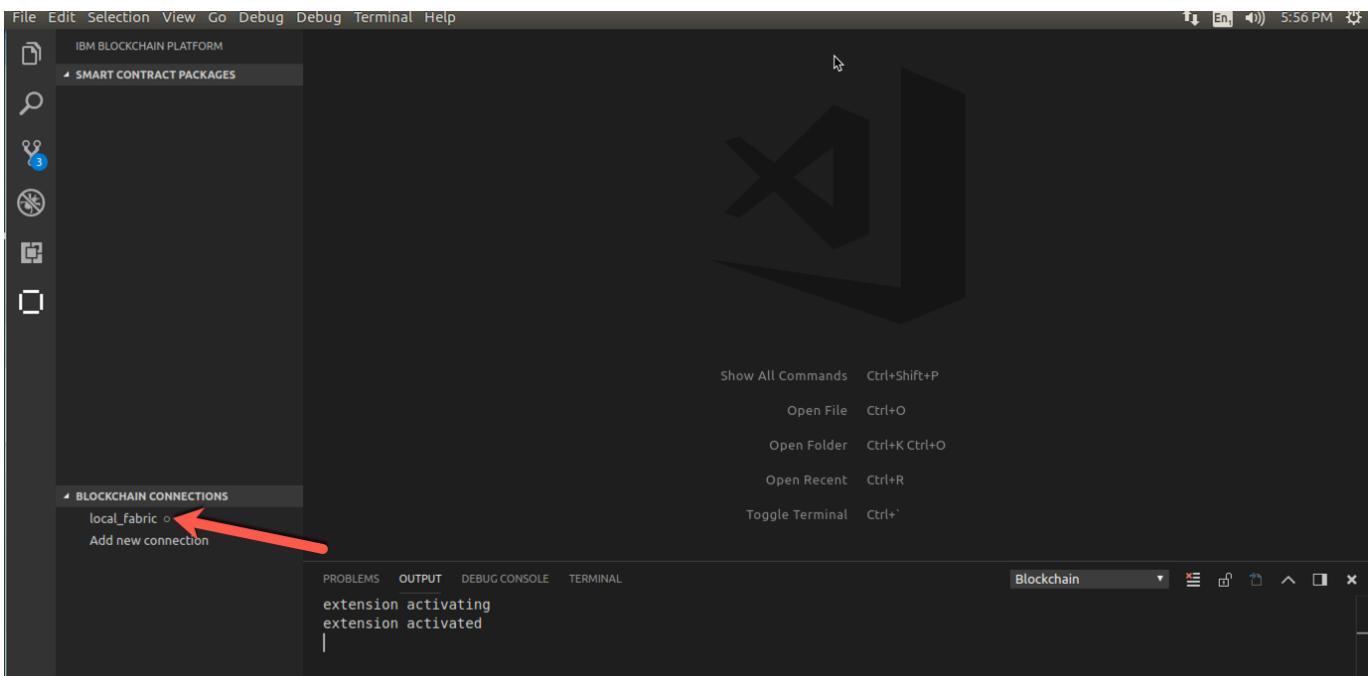
- 1 Invoke the VS Code editor from the user home directory

```
cd ~
code
```

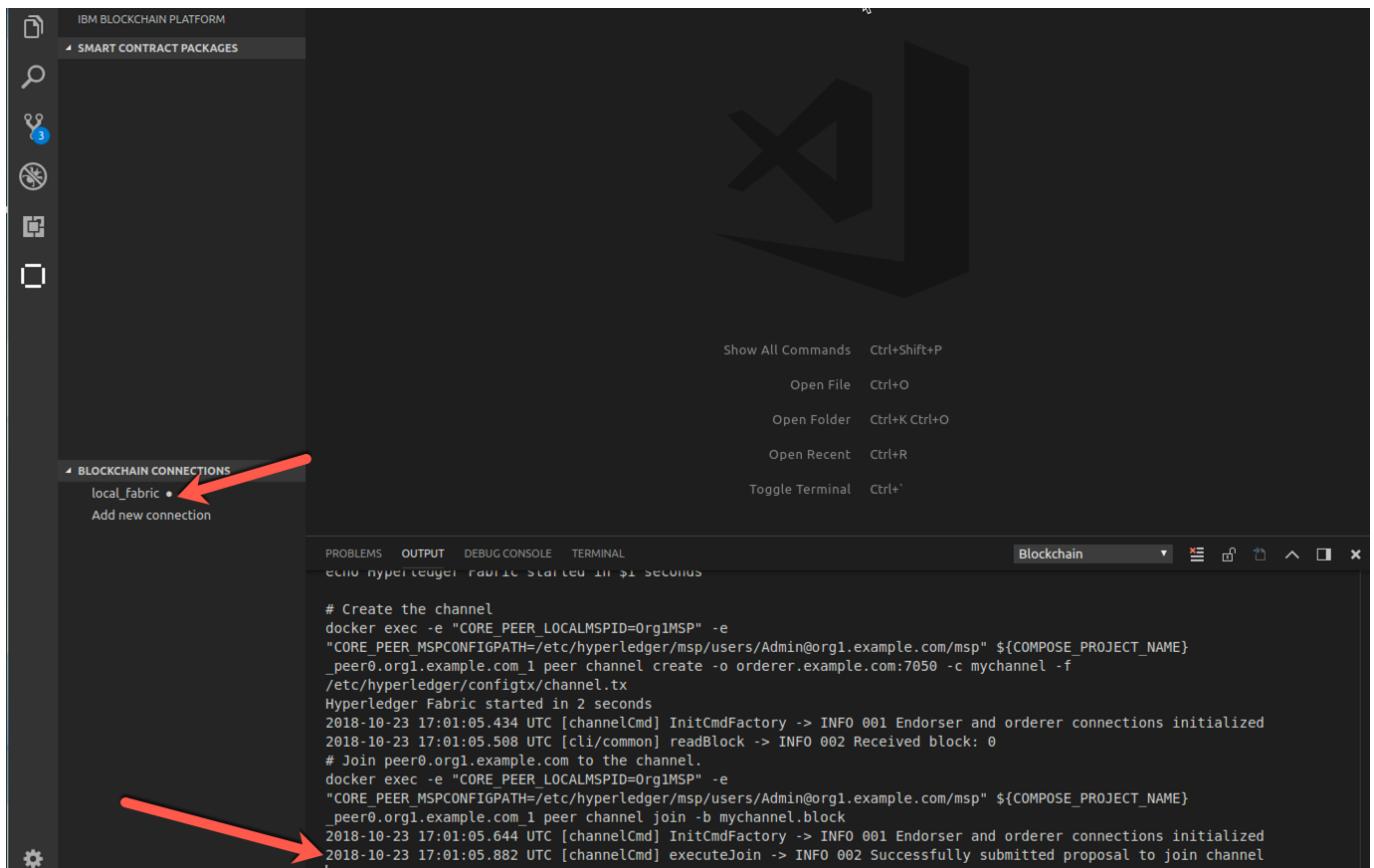
- 2 Close any tabs that may be open from the previous lab(s).
- 3 Click on the icon as shown below to open the IBM Blockchain Platform view.



- 4 You should see the extension activating/activated messages below in the Output pane. Click on the **local\_fabric** instance under Blockchain Connections pane to start and connect to a local Hyperledger Fabric instance.



- 5 The **local\_fabric** instance under Blockchain Connections pane should indicate you are connected with a filled in circle to the right of the instance and the output window should indicate the local Hyperledger Fabric instance has been successfully started as indicated by the **INFO 002 Successfully submitted proposal to join channel** message. Click on the **local\_fabric** instance to expand it.



```

IBM BLOCKCHAIN PLATFORM
SMART CONTRACT PACKAGES

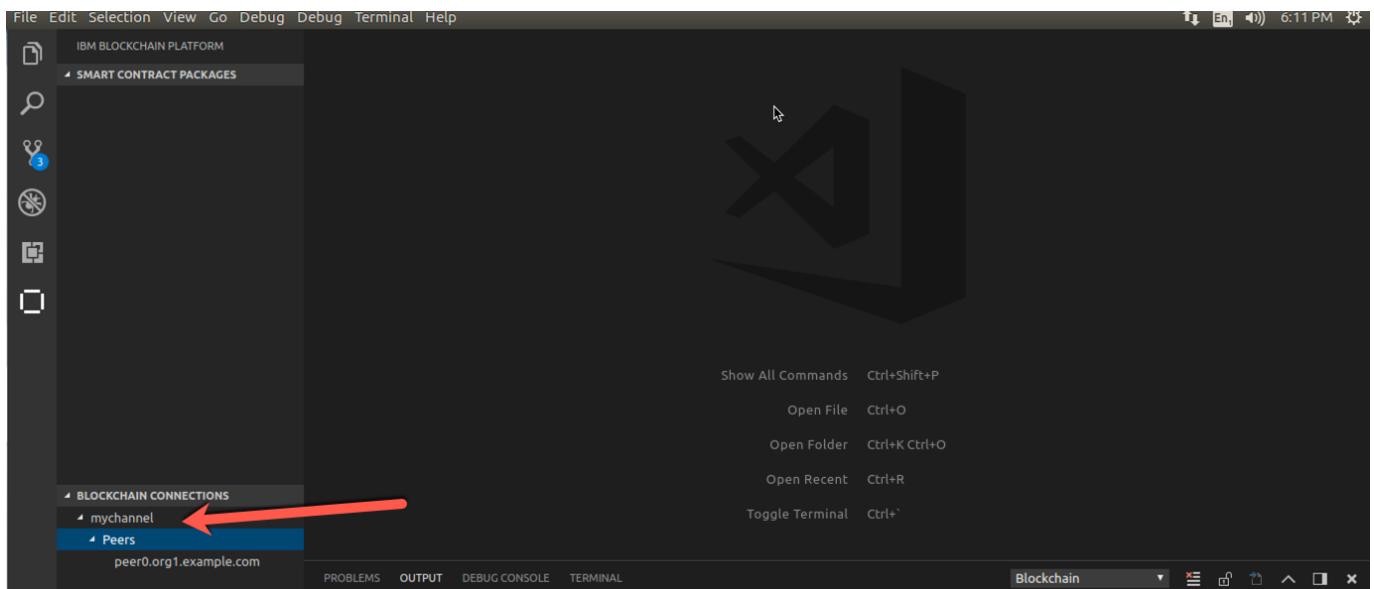
BLOCKCHAIN CONNECTIONS
local_fabric •
Add new connection

PROBLEMS OUTPUT DEBUG CONSOLE TERMINAL
echo hyperledger fabric started in $1 seconds

Create the channel
docker exec -e "CORE_PEER_LOCALMSPID=Org1MSP" -e
"CORE_PEER_MSPCONFIGPATH=/etc/hyperledger/msp/users/Admin@org1.example.com/msp" ${COMPOSE_PROJECT_NAME}
_peer0.org1.example.com 1 peer channel create -o orderer.example.com:7050 -c mychannel -f
/etc/hyperledger/configtx/channel.tx
Hyperledger Fabric started in 2 seconds
2018-10-23 17:01:05.434 UTC [channelCmd] InitCmdFactory -> INFO 001 Endorser and orderer connections initialized
2018-10-23 17:01:05.508 UTC [cli/common] readBlock -> INFO 002 Received block: 0
Join peer0.org1.example.com to the channel.
docker exec -e "CORE_PEER_LOCALMSPID=Org1MSP" -e
"CORE_PEER_MSPCONFIGPATH=/etc/hyperledger/msp/users/Admin@org1.example.com/msp" ${COMPOSE_PROJECT_NAME}
_peer0.org1.example.com 1 peer channel join -b mychannel.block
2018-10-23 17:01:05.644 UTC [channelCmd] InitCmdFactory -> INFO 001 Endorser and orderer connections initialized
2018-10-23 17:01:05.882 UTC [channelCmd] executeJoin -> INFO 002 Successfully submitted proposal to join channel

```

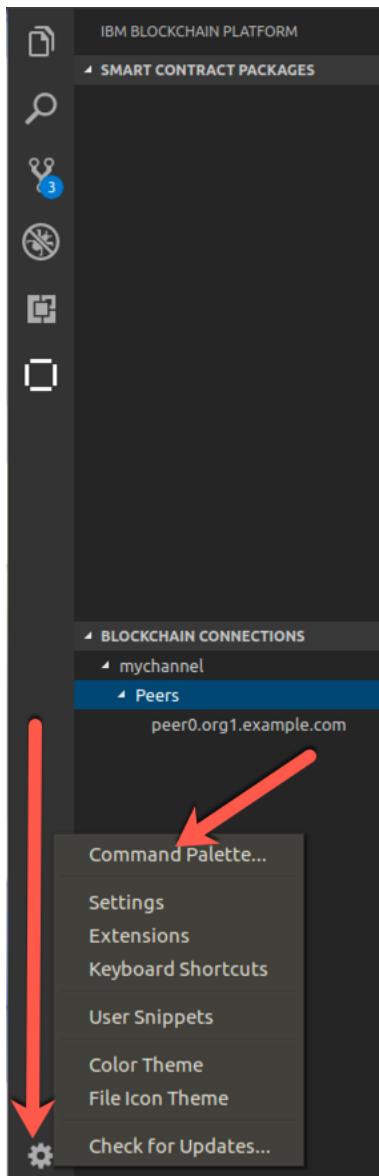
- 6 The **local\_fabric** instance is expanded to display the configured channels and peers. In this case one channel and peer is configured.



## 1.2. Generate a template a smart contract

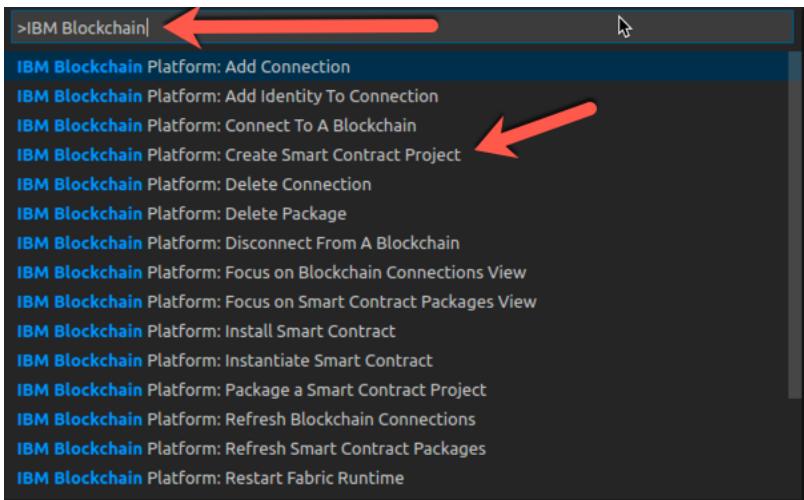
In this section, we will generate a sample template smart contract.

- 8 Click on the gear icon and then Command Palette to bring up a list of commands.

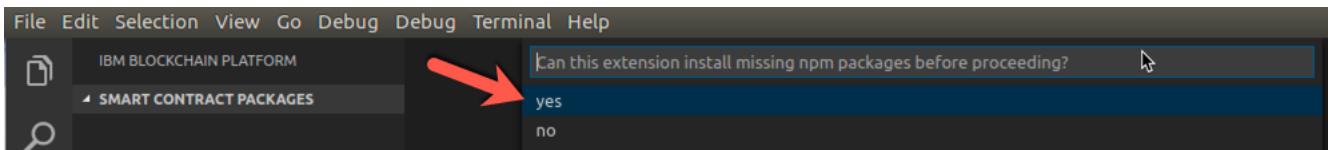


- 9 Enter **IBM Blockchain** in the command palette dialog to filter the search and then click on **IBM Blockchain Platform: Create Smart Contract Project**.

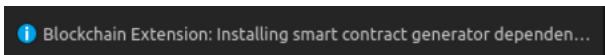
## IBM Blockchain



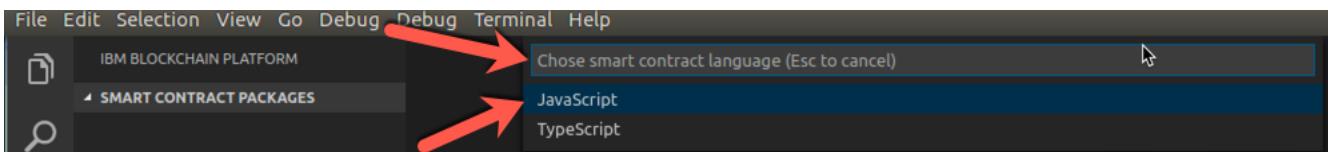
10 Click on **yes** to the **Can this extension install missing npm packages before proceeding?** dialog.



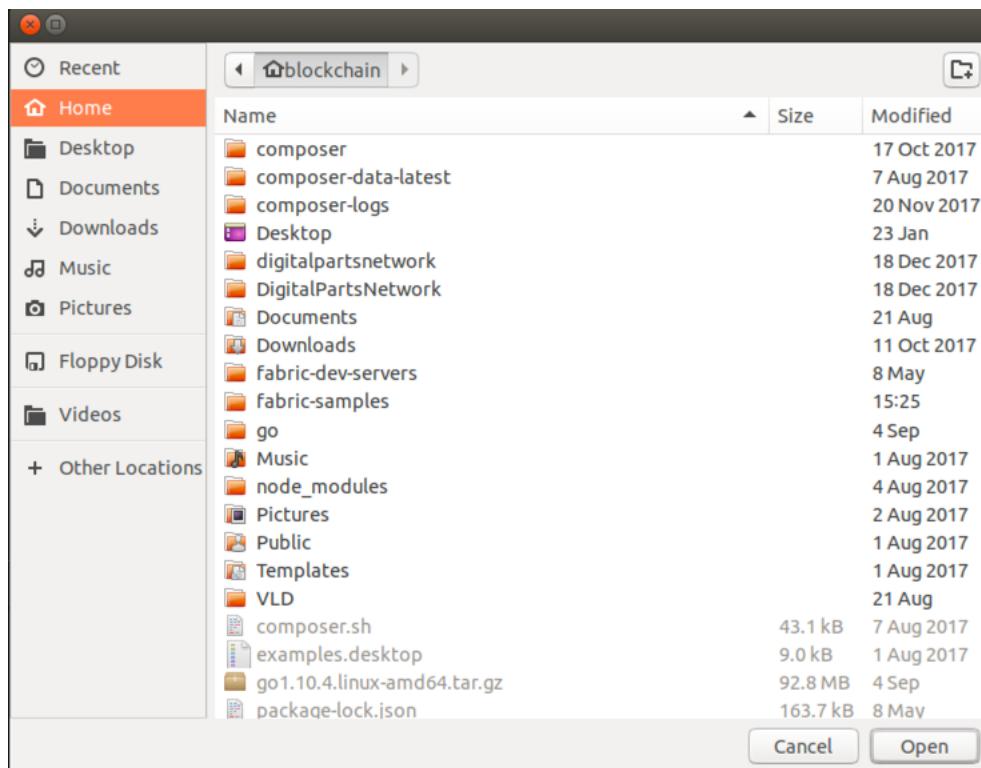
11 In lower right, you will see a message that the extension is installing smart contract generator dependencies.



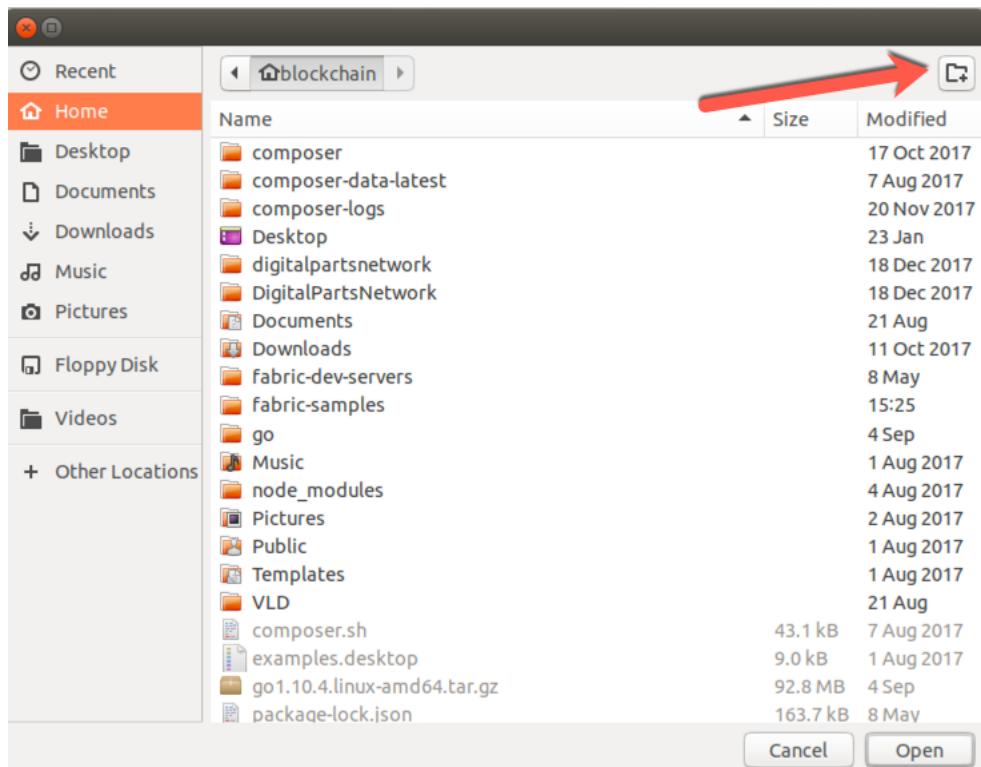
12 Click on **JavaScript** to the **Choose smart contract language (Esc to cancel)** dialog.



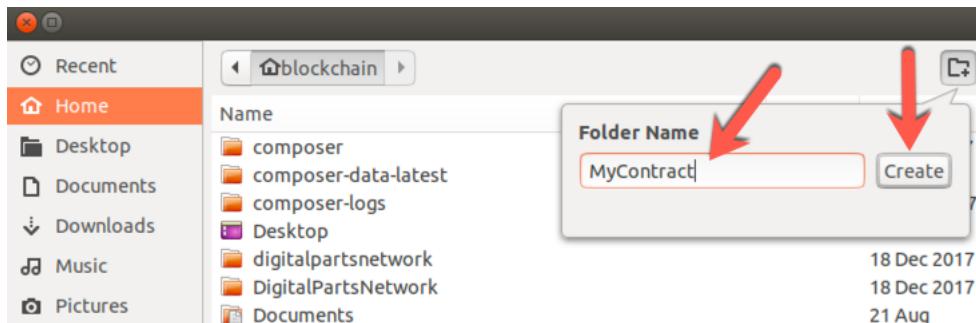
13 A file dialog will appear.



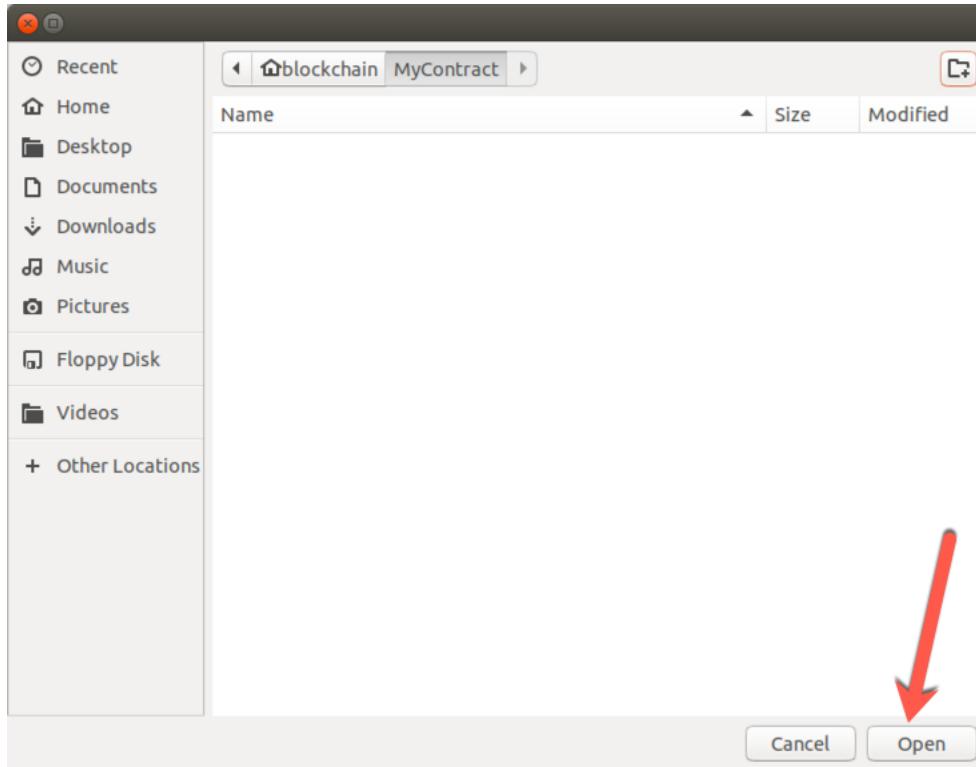
14 On the file dialog, create a new folder by clicking on the new folder icon.



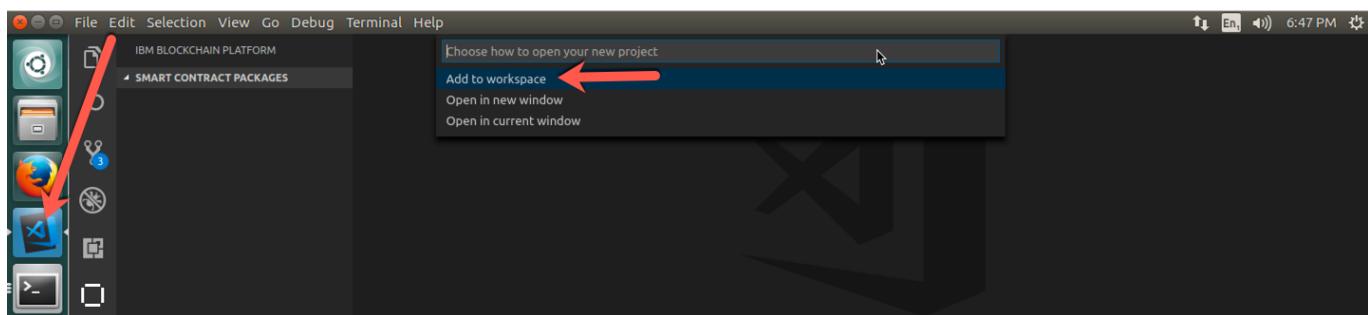
15 In the Folder Name dialog, enter **MyContract** and click the **Create** button.



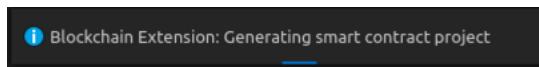
16 Click the **Open** button.



17 Click the **VSCode** icon on the Ubuntu menu bar and then click on **Add to workspace** on the **Choose how to open your new project** dialog.



18 On the lower right within VSCode, you will see the **Generating smart contract project** message. The message will disappear once the smart contract project has been generated.



- 19 Click on the Explorer icon to bring up the Explorer navigation tree. Expand **MyContract->lib** and select **my-contract.js** to view the generated smart contract.

Notice how **MyContract** extends the [Hyperledger Fabric Contract class](#). This built-in class was brought into scope earlier in the program:

```
const {Contract} = require('fabric-contract-api');
```

Our MyContract contract will acquire useful capabilities from the Fabric Contract class, such as automatic method invocation, a per-transaction [context](#), transaction [handlers](#), and class-shared state.

You might have noticed an extra variable in the **instantiate**, **transaction1**, and **transaction2** definitions – ctx. It's called the [transaction context](#), and it's always the first variable. It contains a per-transaction data area to make it easier for [transaction logic](#) to create and recall relevant smart contract information. For example, in this case it would contain a participant's specified transaction identifier and digital identity, as well as access to the ledger API, and a temporary storage area.

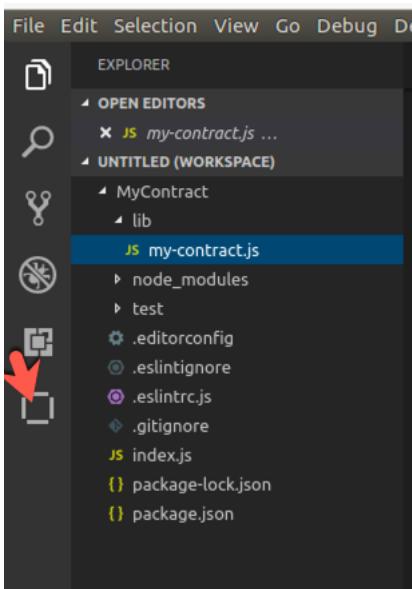
```
File Edit Selection View Go Debug Terminal Help
EXPLORER OPEN EDITORS my-contract.js *
15 * limitations under the License.
16 */
17
18 'use strict';
19
20 const { Contract } = require('fabric-contract-api');
21
22 class MyContract extends Contract {
23
24 async instantiate(ctx) {
25 console.info('instantiate');
26 }
27
28 async transaction1(ctx, arg1) {
29 console.info('transaction1', arg1);
30 }
31
32 async transaction2(ctx, arg1, arg2) {
33 console.info('transaction2', arg1, arg2);
34 }
35
36 }
37
38 module.exports = MyContract;
39
```

PROBLEMS OUTPUT DEBUG CONSOLE TERMINAL
Blockchain extension activating
extension activated

### 1.3. Package, deploy, and instantiate the smart contract

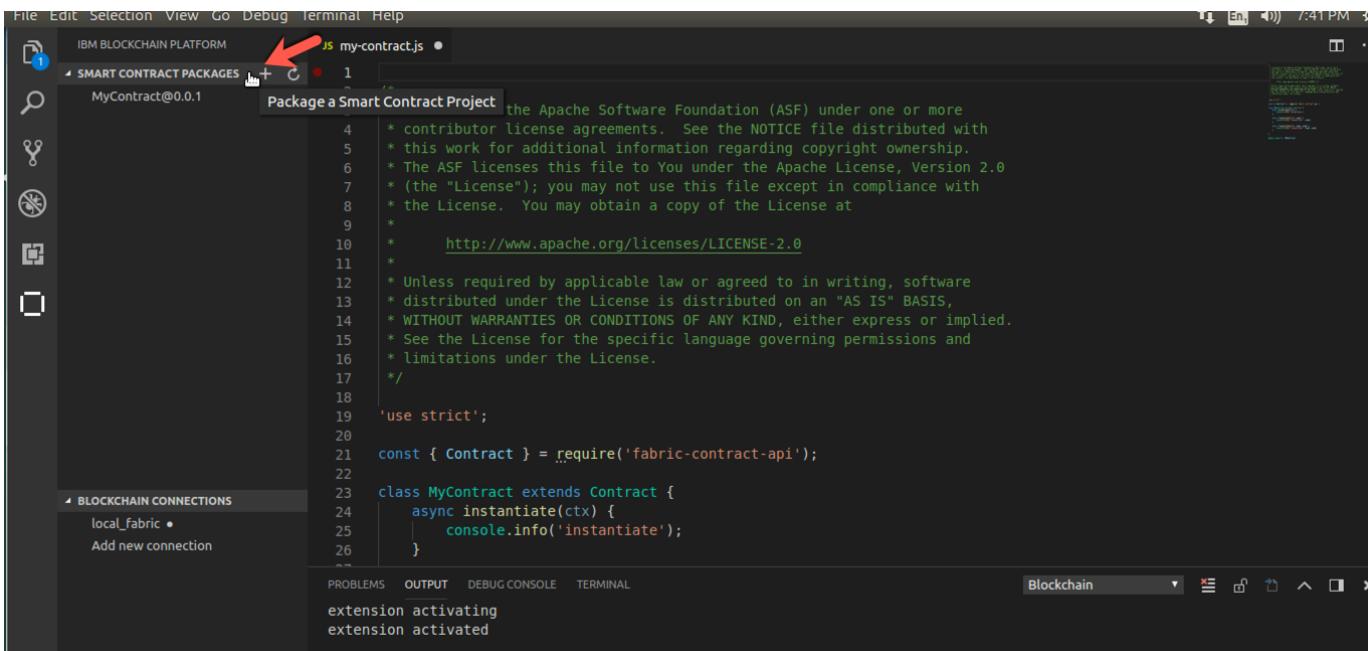
In this section, we will package, deploy, and instantiate the smart contract.

11 Click on the icon as shown below to switch back to the IBM Blockchain Platform view.



12 Click on the Plus + sign next to **SMART CONTRACT PACKAGES**. [MyContract@0.0.1](#) will automatically be added.

The package consists of three parts: **1.** the chaincode as defined by ChaincodeDeploymentSpec. This defines the code and other meta properties such as name and version, **2.** an instantiation policy which can be syntactically described by the same policy used for endorsement and described in endorsement-policies.rst, and **3.** a set of signatures by the entities that “own” the chaincode.



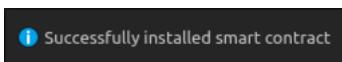
- 13 Deploy the smart contract. Click on **local\_fabric** and expand **mychannel->Peers>peer0.org1.example.com**. Right click on the peer and select **Install Smart Contract**.

```
File Edit Selection View Go Debug Terminal Help
IBM BLOCKCHAIN PLATFORM JS my-contract.js x
SMART CONTRACT PACKAGES MyContract@0.0.1
BLOCKCHAIN CONNECTIONS mychannel Peers
peer0.org1.example.com
Install Smart Contract LEMS OUTPUT DEBUG CONSOLE TERMINAL
Blockchain extension activating
extension activated
```

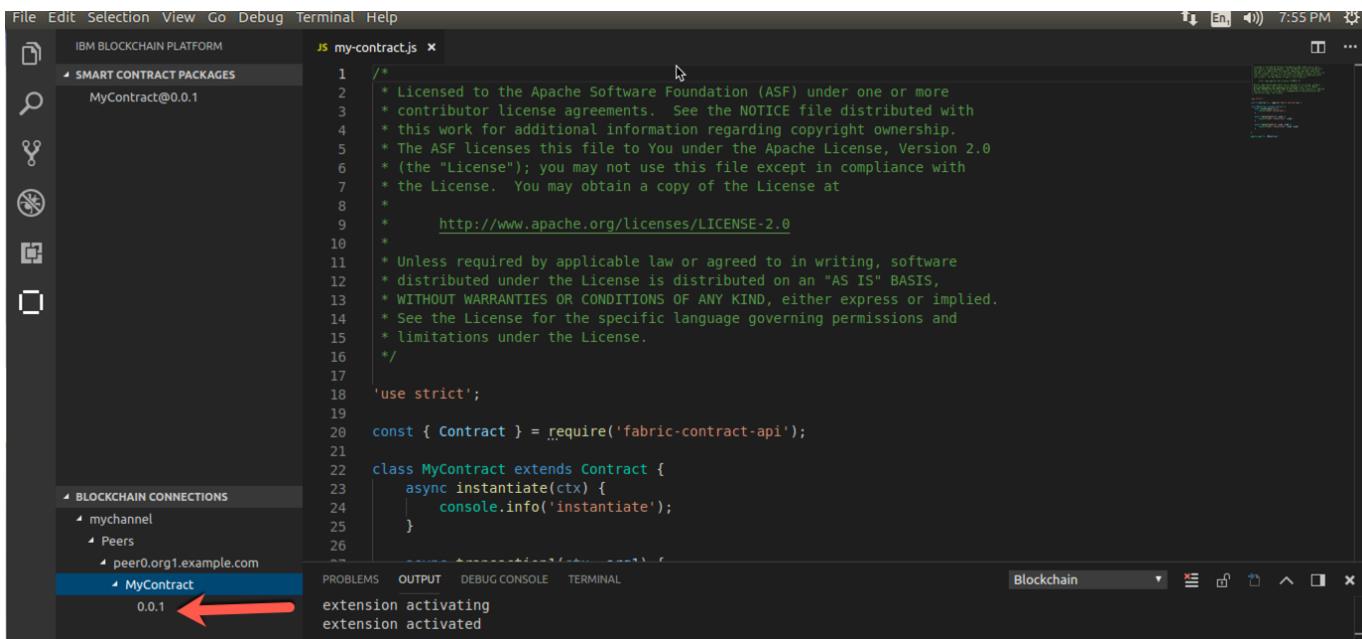
- 14 Select **MyContract 0.0.1** on the **Choose which package to install** on the peer dialog.

The screenshot shows the IBM Blockchain Platform interface. The top navigation bar includes File, Edit, Selection, View, Go, Debug, Terminal, and Help. Below the navigation bar, there's a header with the text "IBM BLOCKCHAIN PLATFORM". A dropdown menu titled "my-contract" is open, displaying the message "Choose which package to install on the peer". Underneath this, a list of packages is shown, with "MyContract 0.0.1" highlighted by a red arrow pointing to it. The sidebar on the left shows a tree view with "SMART CONTRACT PACKAGES" expanded, and "MyContract@0.0.1" listed under it.

- 15 You will see a **Successfully installed smart contract** message on the lower right.

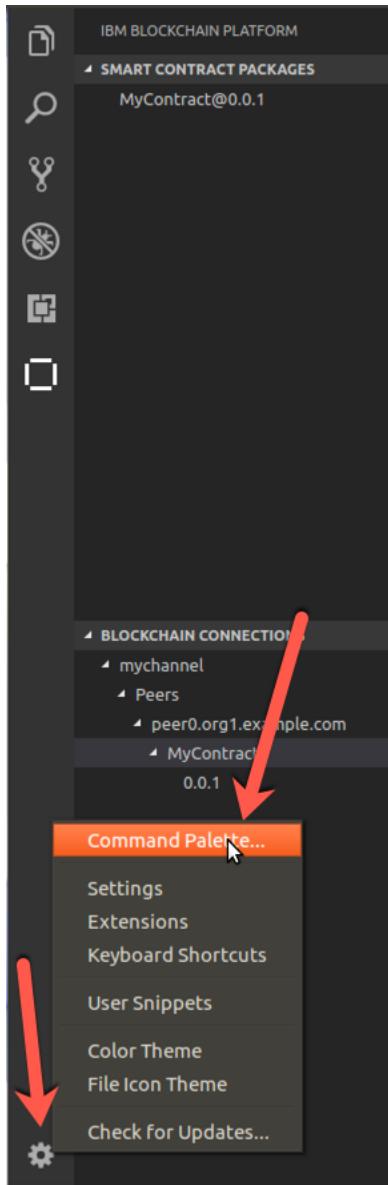


- 16 Expanding the peer, will show the deployed smart contract as shown below.



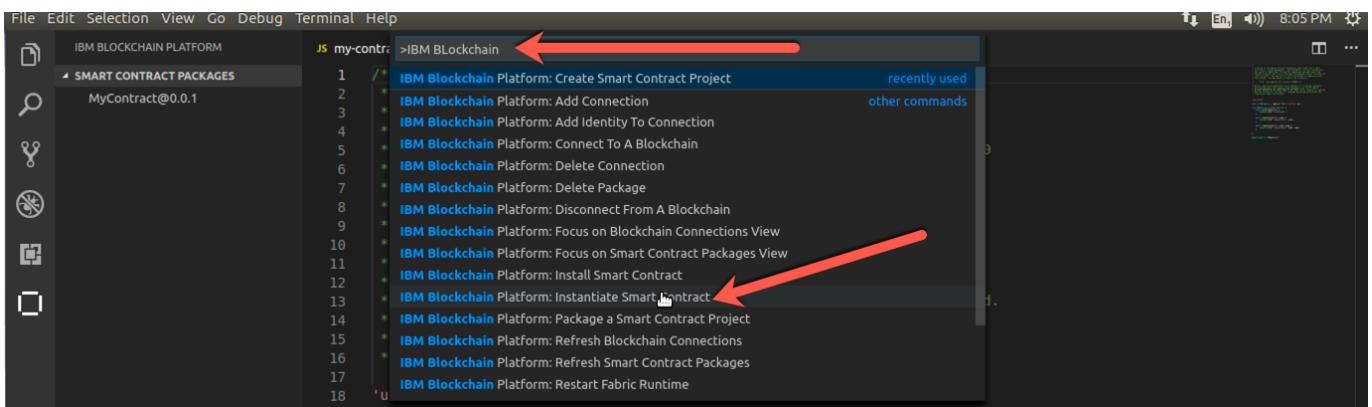
```
File Edit Selection View Go Debug Terminal Help
IBM BLOCKCHAIN PLATFORM
SMART CONTRACT PACKAGES
MyContract@0.0.1
BLOCKCHAIN CONNECTIONS
mychannel
Peers
peer0.org1.example.com
MyContract
0.0.1
JS my-contract.js x
1 /*
2 * Licensed to the Apache Software Foundation (ASF) under one or more
3 * contributor license agreements. See the NOTICE file distributed with
4 * this work for additional information regarding copyright ownership.
5 * The ASF licenses this file to You under the Apache License, Version 2.0
6 * (the "License"); you may not use this file except in compliance with
7 * the License. You may obtain a copy of the License at
8 *
9 * http://www.apache.org/licenses/LICENSE-2.0
10 *
11 * Unless required by applicable law or agreed to in writing, software
12 * distributed under the License is distributed on an "AS IS" BASIS,
13 * WITHOUT WARRANTIES OR CONDITIONS OF ANY KIND, either express or implied.
14 * See the License for the specific language governing permissions and
15 * limitations under the License.
16 */
17
18 'use strict';
19
20 const { Contract } = require('fabric-contract-api');
21
22 class MyContract extends Contract {
23 async instantiate(ctx) {
24 console.info('instantiate');
25 }
26 }
27
28 module.exports = MyContract;
PROBLEMS OUTPUT DEBUG CONSOLE TERMINAL
Blockchain
```

17 Click on the gear icon and then Command Palette to bring up a list of commands.

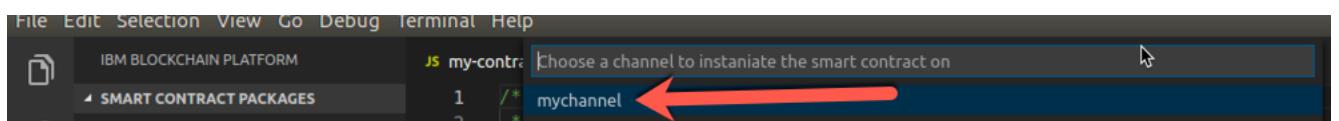


- 18 Instantiate the smart contract. Enter **IBM Blockchain** in the command palette dialog to filter the search and then click on **IBM Blockchain Platform: Instantiate Smart Contract**. Alternatively you can also right click on the channel under the **local-fabric** instance and choose to **Instantiate/Upgrade the Smart Contract**.

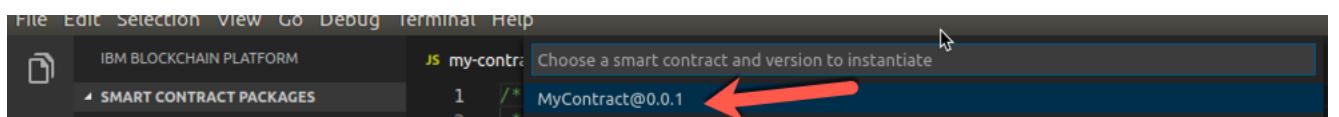
## IBM Blockchain



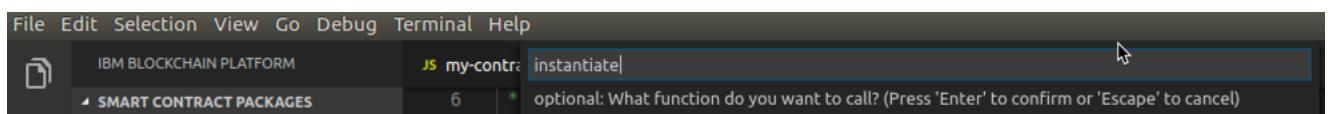
- 19 Click on **mychannel** to the **Choose a channel to instantiate the smart contract on** smart dialog.



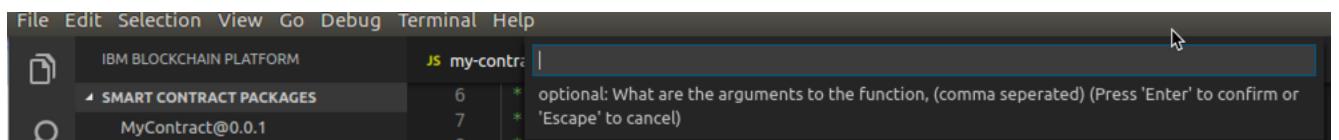
- 20 Click on **MyContract@0.0.1** to the **Choose a smart contract and version to instantiate** dialog.



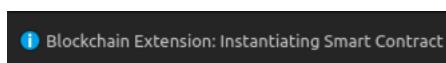
- 21 Enter **instantiate** to the **optional: What function to you want to call?** dialog. Then press enter.



- 22 Press enter to the **optional: What are the arguments to the function ...** dialog.



- 23 You will see the Blockchain Extension: Instantiating Smart Contract message on the lower right.



- 24 Once the smart contract has been successfully instantiated, you will see **Instantiated Smart Contracts** and [MyContract@0.0.1](#) show up under **mychannel**.

The screenshot shows the IBM Blockchain Platform IDE interface. On the left, there's a sidebar with icons for file operations, search, and connections. The main area displays a code editor for a file named `my-contract.js`. The code defines a smart contract class `MyContract` that extends the `Contract` class from the `fabric-contract-api`. It includes methods for instantiating the contract and performing two types of transactions. Below the code editor, the `Blockchain` tab is selected, showing a list of blockchain connections. One connection is highlighted: `mychannel` under `Peers`, with `peer0.org1.example.com` and `MyContract` listed. A red arrow points to the `Instantiated Smart Contracts` section, which contains the entry `MyContract@0.0.1`. The status bar at the bottom indicates the time as 8:23 PM.

## 1.4. Test the smart contract

In this section we will test the smart contract that has been generated, deployed, and instantiated.

- 1 Switch back to the Explorer view by clicking on the Explorer icon.

The screenshot shows the IBM Blockchain Platform IDE interface. The Explorer icon (a folder icon) is highlighted with a red arrow. The sidebar and code editor are identical to the previous screenshot. The `Blockchain` tab is still selected, but the view has changed to the Explorer. The `Instantiated Smart Contracts` section now shows the entry `MyContract@0.0.1` under the `mychannel` connection. The status bar at the bottom indicates the time as 8:29 PM.

- 2 In the smart contract navigation tree, expand **test** and click on **my-contract.js**. This is a Node.js module we will invoke with the npm test. Note the test module will exercise all three transactions.

```

File Edit Selection View Go Debug Terminal Help
EXPLORER JS my-contract.js lib JS my-contract.js test x
OPEN EDITORS JS my-contract.js lib JS my-contract.js ...
UNTITLED (WORKSPACE) JS my-contract.js ...
MyContract lib my-contract.js node_modules test
.my-contract.js
.editorconfig .eslintignore .eslintrc.js .gitignore index.js package-lock.json package.json
JS my-contract.js
PROBLEMS OUTPUT DEBUG CONSOLE TERMINAL
Blockchain
extension activating
extension activated
Instantiating with function: 'instantiate' and arguments: 'undefined'

```

- 3 Right click on **my-contract.js** and select **Open in Terminal**.

```

File Edit Selection View Go Debug Terminal Help
EXPLORER JS my-contract.js lib JS my-contract.js test x
OPEN EDITORS JS my-contract.js lib JS my-contract.js ...
UNTITLED (WORKSPACE) JS my-contract.js ...
MyContract lib my-contract.js node_modules test
.my-contract.js
.editorconfig .eslintignore .eslintrc.js .gitignore index.js package-lock.json package.json
JS my-contract.js
Open to the Side Ctrl+Enter
Open Containing Folder Alt+Ctrl+R
Open in Terminal
Select for Compare
Copy Ctrl+C
Copy Path Alt+Ctrl+C
Copy Relative Path Alt+Ctrl+Shift+C
Rename F2
Delete Del
Export Workspace Diagrams

```

- 4 We will test this module with npm test. This will run the Node.js package's test script using the Mocha test framework as defined in the package.json file. The test module uses a stub interface to unit test the functions. This is useful for initial unit testing before connecting to real systems or blockchain network. Mocha is a feature-rich JavaScript test framework running on [Node.js](#) and in the browser. Mocha tests run serially, allowing for flexible and accurate reporting, while mapping uncaught exceptions to the correct test cases.

5 Enter the following on the terminal window as show below:

```
npm test
```

The screenshot shows a terminal window in VS Code with the command `npm test` entered at the bottom. A red arrow points from the text above to this terminal input field. The terminal output area is currently empty.

6 You should see the output below in the terminal window. All tests have succeeded.

The screenshot shows the IBM Blockchain Platform IDE interface. The left sidebar displays the project structure with files like `my-contract.js`, `index.js`, and `package.json`. The main editor window shows a JavaScript file named `my-contract.js test` containing Jest test cases for a contract named `MyContract`. A red arrow points from the text "Click on the icon as shown below to Disconnect from a Blockchain." to the terminal output area. The terminal shows the command `nyc mocha --recursive` being run, followed by the test results:

```
> MyContract@0.0.1 test /home/blockchain/MyContract
> nyc mocha --recursive

MyContract
 #instantiate
 instantiate
 ✓ should work
 #transaction1
 transaction1 hello
 ✓ should work
 #transaction2
 transaction2 hello world
 ✓ should work

 3 passing (25ms)

=====
Statements : 100% (8/8)
Branches : 100% (0/0)
Functions : 100% (3/3)
Lines : 100% (8/8)
```

## 1.5. Lab Cleanup

- 6 Navigate back to the IBM Blockchain Platform view. You should know how to do this by now.
- 7 Click on the icon as shown below to **Disconnect from a Blockchain**.

File Edit Selection View Go Debug Terminal Help

IBM BLOCKCHAIN PLATFORM

SMART CONTRACT PACKAGES

MyContract@0.0.1

BLOCKCHAIN CONNECTIONS

- mychannel
  - Peers
    - peer0.org1.example.com
      - MyContract
      - 0.0.1

package.json

```

1 {
2 "name": "MyContract",
3 "version": "0.0.1",
4 "description": "My Smart Contract",
5 "main": "index.js",
6 "engines": {
7 "node": ">=8",
8 "npm": ">=5"
9 },
10 "scripts": {
11 "lint": "eslint .",
12 "pretest": "npm run lint",
13 "test": "nyc mocha --recursive",
14 "start": "fabric-chaincode-node start"
15 },
16 "engineStrict": true,
17 "author": "John Doe",
18 "license": "Apache-2.0",
19 "dependencies": {
20
21
22
23
24
25
26
27
28
29
2

```

PROBLEMS OUTPUT DEBUG CONSOLE TERMINAL

1: bash

> MyContract@0.0.1 test /home/blockchain/MyContract  
> nyc mocha --recursive

MyContract  
#instantiate  
instantiate  
✓ should work

## 8 Right click on **local\_fabric** and select **Stop Fabric Runtime**.

File Edit Selection View Go Debug Terminal Help

IBM BLOCKCHAIN PLATFORM

SMART CONTRACT PACKAGES

MyContract@0.0.1

BLOCKCHAIN CONNECTIONS

- local\_fabric
  - Add new connection
  - Restart Fabric Runtime
  - Stop Fabric Runtime**
  - Toggle Development Mode

package.json

```

1 {
2 "name": "MyContract",
3 "version": "0.0.1",
4 "description": "My Smart Contract",
5 "main": "index.js",
6 "engines": {
7 "node": ">=8",
8 "npm": ">=5"
9 },
10 "scripts": {
11 "lint": "eslint .",
12 "pretest": "npm run lint",
13 "test": "nyc mocha --recursive",
14 "start": "fabric-chaincode-node start"
15 },
16 "engineStrict": true,
17 "author": "John Doe",
18 "license": "Apache-2.0",
19 "dependencies": {
20
21
22
23
24
25
26
27
28
29
2

```

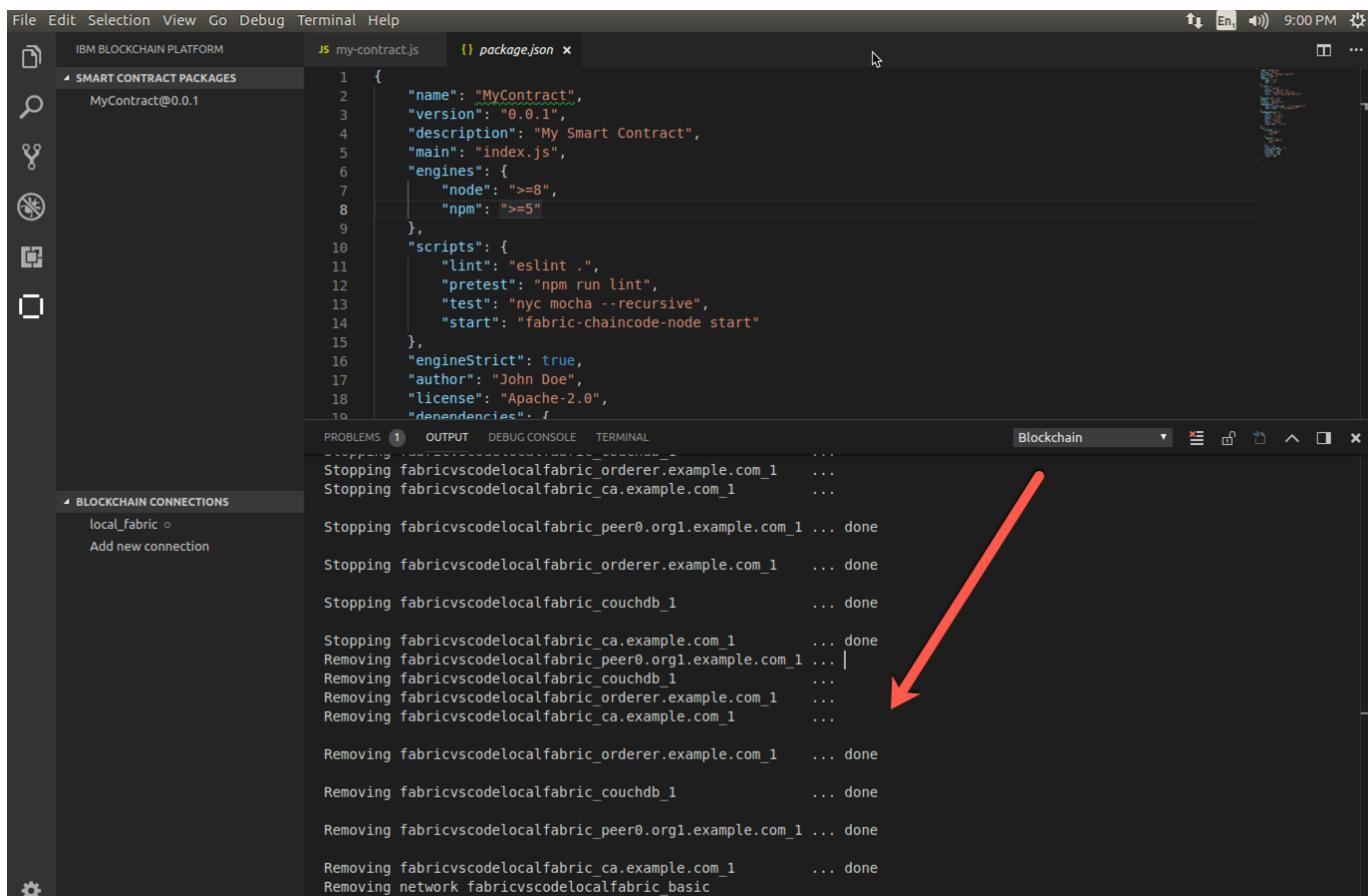
PROBLEMS OUTPUT DEBUG CONSOLE TERMINAL

1: bash

> MyContract@0.0.1 test /home/blockchain/MyContract  
> nyc mocha --recursive

MyContract  
#instantiate  
instantiate  
✓ should work

## 9 The output pane will show the Hyperledger Fabric instance has been stopped as shown below.



The screenshot shows the IBM Blockchain Platform extension in VSCode. The left sidebar displays 'SMART CONTRACT PACKAGES' with 'MyContract@0.0.1'. The right sidebar shows 'BLOCKCHAIN CONNECTIONS' with 'local\_fabric' selected. The main area has two tabs: 'my-contract.js' and 'package.json'. The 'package.json' tab contains the following code:

```
1 {
2 "name": "MyContract",
3 "version": "0.0.1",
4 "description": "My Smart Contract",
5 "main": "index.js",
6 "engines": [
7 "node": ">=8",
8 "npm": ">=5"
9],
10 "scripts": {
11 "lint": "eslint .",
12 "pretest": "npm run lint",
13 "test": "nyc mocha --recursive",
14 "start": "fabric-chaincode-node start"
15 },
16 "engineStrict": true,
17 "author": "John Doe",
18 "license": "Apache-2.0",
19 "dependencies": {}
}
```

The terminal at the bottom shows the command to stop Docker containers:

```
Stopping fabricvscodefabric_orderer.example.com_1 ...
Stopping fabricvscodefabric_ca.example.com_1 ...
Stopping fabricvscodefabric_peer0.org1.example.com_1 ... done
Stopping fabricvscodefabric_orderer.example.com_1 ... done
Stopping fabricvscodefabric_couchdb_1 ... done
Stopping fabricvscodefabric_ca.example.com_1 ... done
Removing fabricvscodefabric_peer0.org1.example.com_1 ... |
Removing fabricvscodefabric_couchdb_1 ...
Removing fabricvscodefabric_orderer.example.com_1 ...
Removing fabricvscodefabric_ca.example.com_1 ...
Removing fabricvscodefabric_orderer.example.com_1 ... done
Removing fabricvscodefabric_couchdb_1 ... done
Removing fabricvscodefabric_peer0.org1.example.com_1 ... done
Removing fabricvscodefabric_ca.example.com_1 ... done
Removing network fabricvscodefabric_basic
```

A red arrow points from the text '10 Close VSCode by choosing File->Exit from the VSCode menu bar.' to the 'Blockchain' tab in the top right corner of the VSCode interface.

10 Close VSCode by choosing File->Exit from the VSCode menu bar.

---

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Please Recycle

# **IBM Blockchain Hands-On**

## **Go Chaincode and Testing in Development Mode**

Lab Five

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## Overview

What is Chaincode? Chaincode is a program, written in [Go](#), [node.js](#), or [Java](#) that implements a prescribed interface. Chaincode runs in a secured Docker container isolated from the endorsing peer process. Chaincode initializes and manages the ledger state through transactions submitted by applications.

A chaincode typically handles business logic agreed to by members of the network, so it is similar to a “smart contract”. A chaincode can be invoked to update or query the ledger in a proposal transaction. Given the appropriate permission, a chaincode may invoke another chaincode, either in the same channel or in different channels, to access its state. Note that, if the called chaincode is on a different channel from the calling chaincode, only read query is allowed. That is, the called chaincode on a different channel is only a [Query](#), which does not participate in state validation checks in subsequent commit phase.

## Chaincode APIs

In the following sections, we will explore chaincode through the eyes of an application developer. We'll present a simple chaincode sample application and walk through the purpose of each method in the Chaincode Shim API.

There is another set of chaincode APIs that allow the client (submitter) identity to be used for access control decisions, whether that is based on client identity itself, or the org identity, or on a client identity attribute. For example, an asset that is represented as a key/value may include the client's identity, and only this client may be authorized to make updates to the key/value. The client identity library has APIs that chaincode can use to retrieve this submitter information to make such access control decisions. We won't cover that in this tutorial, however it is [documented here](#).

Every chaincode program must implement the `Chaincode` interface:

- [Go](#)
- [node.js](#)
- [Java](#)

whose methods are called in response to received transactions. In particular the `Init` method is called when a chaincode receives an `instantiate` or `upgrade` transaction so that the chaincode may perform any necessary initialization, including initialization of application state. The `Invoke` method is called in response to receiving an `invoke` transaction to process transaction proposals.

The other interface in the chaincode “shim” APIs is the `ChaincodeStubInterface`:

- [Go](#)
- [node.js](#)
- [Java](#)

which is used to access and modify the ledger, and to make invocations between chaincodes.

In this tutorial using Go chaincode, we will demonstrate the use of these APIs by implementing a simple chaincode application that manages simple “assets”.

# Writing Simple Asset Chaincode

Our application is a basic sample chaincode to create assets (key-value pairs) on the ledger.

## 1.1. Perform prerequisite lab cleanup

- 1 Start a terminal
- 2 cd ~/fabric-samples/first-network
- 3 Issue the following command to shutdown any existing blockchain networks. Answer 'Y' to the Continue prompt.

```
./byfn.sh down
```

- 4 Issue the following command to kill any active or stale containers:

```
docker rm -f $(docker ps -aq)
```

- 5 Issue the following command to clear any cached networks. Answer 'Y' to the Continue prompt.

```
docker network prune
```

- 6 Delete the underlying chaincode image for the fabcar smart contract.

```
docker rmi dev-peer0.org1.example.com-fabcar-1.0-5c906e402ed29f20260ae42283216aa75549c571e2e380f3615826365d8269ba
```

## 1.2. Choosing a Location for the Code

If you haven't been doing programming in Go, you may want to make sure that you have [Go Programming Language](#) installed and your system properly configured.

Now, you will want to create a directory for your chaincode application as a child directory of [\\$GOPATH/src/](#).

To keep things simple, let's use the following command:

```
mkdir -p $GOPATH/src/sacc && cd $GOPATH/src/sacc
```

Now, let's create the source file that we'll fill in with code:

```
touch sacc.go
```

## Housekeeping

First, let's start with some housekeeping. As with every chaincode, it implements the [Chaincode interface](#) in particular, `Init` and `Invoke` functions. So, let's add the Go import statements for the necessary dependencies for our chaincode. We'll import the chaincode shim package and the [peer protobuf package](#). Next, let's add a struct `SimpleAsset` as a receiver for Chaincode shim functions.

```
package main

import (
 "fmt"

 "github.com/hyperledger/fabric/core/chaincode/shim"
 "github.com/hyperledger/fabric/protos/peer"
)

// SimpleAsset implements a simple chaincode to manage an asset
type SimpleAsset struct {
```

## Initializing the Chaincode

Next, we'll implement the `Init` function.

```
// Init is called during chaincode instantiation to initialize any data.
func (t *SimpleAsset) Init(stub shim.ChaincodeStubInterface) peer.Response {
}
```

### Note

Note that chaincode upgrade also calls this function. When writing a chaincode that will upgrade an existing one, make sure to modify the `Init` function appropriately. In particular, provide an empty “`Init`” method if there's no “migration” or nothing to be initialized as part of the upgrade.

Next, we'll retrieve the arguments to the `Init` call using the [ChaincodeStubInterface.GetStringArgs](#) function and check for validity. In our case, we are expecting a key-value pair.

```
// Init is called during chaincode instantiation to initialize any
// data. Note that chaincode upgrade also calls this function to reset
// or to migrate data, so be careful to avoid a scenario where you
// inadvertently clobber your ledger's data!
func (t *SimpleAsset) Init(stub shim.ChaincodeStubInterface) peer.Response {
 // Get the args from the transaction proposal
 args := stub.GetStringArgs()
 if len(args) != 2 {
 return shim.Error("Incorrect arguments. Expecting a key and a value")
 }
}
```

```
}
```

Next, now that we have established that the call is valid, we'll store the initial state in the ledger. To do this, we will call [ChaincodeStubInterface.PutState](#) with the key and value passed in as the arguments. Assuming all went well, return a peer.Response object that indicates the initialization was a success.

```
// Init is called during chaincode instantiation to initialize any
// data. Note that chaincode upgrade also calls this function to reset
// or to migrate data, so be careful to avoid a scenario where you
// inadvertently clobber your ledger's data!
func (t *SimpleAsset) Init(stub shim.ChaincodeStubInterface) peer.Response {
 // Get the args from the transaction proposal
 args := stub.GetStringArgs()
 if len(args) != 2 {
 return shim.Error("Incorrect arguments. Expecting a key and a value")
 }

 // Set up any variables or assets here by calling stub.PutState()

 // We store the key and the value on the ledger
 err := stub.PutState(args[0], []byte(args[1]))
 if err != nil {
 return shim.Error(fmt.Sprintf("Failed to create asset: %s", args[0]))
 }
 return shim.Success(nil)
}
```

## Invoking the Chaincode

First, let's add the [Invoke](#) function's signature.

```
// Invoke is called per transaction on the chaincode. Each transaction is
// either a 'get' or a 'set' on the asset created by Init function. The 'set'
// method may create a new asset by specifying a new key-value pair.
func (t *SimpleAsset) Invoke(stub shim.ChaincodeStubInterface) peer.Response {
}
```

As with the [Init](#) function above, we need to extract the arguments from the [ChaincodeStubInterface](#). The [Invoke](#) function's arguments will be the name of the chaincode application function to invoke. In our case, our application will simply have two functions: [set](#) and [get](#), that allow the value of an asset to be set or its current state to be retrieved.

We first call [ChaincodeStubInterface.GetFunctionAndParameters](#) to extract the function name and the parameters to that chaincode application function.

```
// Invoke is called per transaction on the chaincode. Each transaction is
// either a 'get' or a 'set' on the asset created by Init function. The Set
// method may create a new asset by specifying a new key-value pair.
func (t *SimpleAsset) Invoke(stub shim.ChaincodeStubInterface) peer.Response {
 // Extract the function and args from the transaction proposal
 fn, args := stub.GetFunctionAndParameters()

}
```

Next, we'll validate the function name as being either `set` or `get`, and invoke those chaincode application functions, returning an appropriate response via the `shim.Success` or `shim.Error` functions that will serialize the response into a gRPC protobuf message.

```
// Invoke is called per transaction on the chaincode. Each transaction is
// either a 'get' or a 'set' on the asset created by Init function. The Set
// method may create a new asset by specifying a new key-value pair.
func (t *SimpleAsset) Invoke(stub shim.ChaincodeStubInterface) peer.Response {
 // Extract the function and args from the transaction proposal
 fn, args := stub.GetFunctionAndParameters()

 var result string
 var err error
 if fn == "set" {
 result, err = set(stub, args)
 } else {
 result, err = get(stub, args)
 }
 if err != nil {
 return shim.Error(err.Error())
 }

 // Return the result as success payload
 return shim.Success([]byte(result))
}
```

## Implementing the Chaincode Application

As noted, our chaincode application implements two functions that can be invoked via the `Invoke` function. Let's implement those functions now. Note that as we mentioned above, to access the ledger's state, we will leverage the `ChaincodeStubInterface.PutState` and `ChaincodeStubInterface.GetState` functions of the chaincode shim API.

```
// Set stores the asset (both key and value) on the ledger. If the key exists,
// it will override the value with the new one
func set(stub shim.ChaincodeStubInterface, args []string) (string, error) {
 if len(args) != 2 {
 return "", fmt.Errorf("Incorrect arguments. Expecting a key and a value")
 }

 err := stub.PutState(args[0], []byte(args[1]))
 if err != nil {
 return "", fmt.Errorf("Failed to set asset: %s", args[0])
 }
 return args[1], nil
}

// Get returns the value of the specified asset key
func get(stub shim.ChaincodeStubInterface, args []string) (string, error) {
 if len(args) != 1 {
 return "", fmt.Errorf("Incorrect arguments. Expecting a key")
 }

 value, err := stub.GetState(args[0])
 if err != nil {
 return "", fmt.Errorf("Failed to get asset: %s with error: %s", args[0], err)
 }
 return string(value), nil
}
```

```

 }
 if value == nil {
 return "", fmt.Errorf("Asset not found: %s", args[0])
 }
 return string(value), nil
}

```

## Pulling it All Together

Finally, we need to add the `main` function, which will call the `shim.Start` function. Here's the whole chaincode program source.

```

package main

import (
 "fmt"

 "github.com/hyperledger/fabric/core/chaincode/shim"
 "github.com/hyperledger/fabric/protos/peer"
)

// SimpleAsset implements a simple chaincode to manage an asset
type SimpleAsset struct {
}

// Init is called during chaincode instantiation to initialize any
// data. Note that chaincode upgrade also calls this function to reset
// or to migrate data.
func (t *SimpleAsset) Init(stub shim.ChaincodeStubInterface) peer.Response {
 // Get the args from the transaction proposal
 args := stub.GetStringArgs()
 if len(args) != 2 {
 return shim.Error("Incorrect arguments. Expecting a key and a value")
 }

 // Set up any variables or assets here by calling stub.PutState()

 // We store the key and the value on the ledger
 err := stub.PutState(args[0], []byte(args[1]))
 if err != nil {
 return shim.Error(fmt.Sprintf("Failed to create asset: %s", args[0]))
 }
 return shim.Success(nil)
}

// Invoke is called per transaction on the chaincode. Each transaction is
// either a 'get' or a 'set' on the asset created by Init function. The Set
// method may create a new asset by specifying a new key-value pair.
func (t *SimpleAsset) Invoke(stub shim.ChaincodeStubInterface) peer.Response {
 // Extract the function and args from the transaction proposal
 fn, args := stub.GetFunctionAndParameters()

 var result string
 var err error
 if fn == "set" {
 result, err = set(stub, args)
 } else { // assume 'get' even if fn is nil
 result, err = get(stub, args)
 }
 if err != nil {
 return shim.Error(err.Error())
 }
 return shim.Success(result)
}

```

```

 }
 if err != nil {
 return shim.Error(err.Error())
 }

 // Return the result as success payload
 return shim.Success([]byte(result))
}

// Set stores the asset (both key and value) on the ledger. If the key exists,
// it will override the value with the new one
func set(stub shim.ChaincodeStubInterface, args []string) (string, error) {
 if len(args) != 2 {
 return "", fmt.Errorf("Incorrect arguments. Expecting a key and a value")
 }

 err := stub.PutState(args[0], []byte(args[1]))
 if err != nil {
 return "", fmt.Errorf("Failed to set asset: %s", args[0])
 }
 return args[1], nil
}

// Get returns the value of the specified asset key
func get(stub shim.ChaincodeStubInterface, args []string) (string, error) {
 if len(args) != 1 {
 return "", fmt.Errorf("Incorrect arguments. Expecting a key")
 }

 value, err := stub.GetState(args[0])
 if err != nil {
 return "", fmt.Errorf("Failed to get asset: %s with error: %s", args[0], err)
 }
 if value == nil {
 return "", fmt.Errorf("Asset not found: %s", args[0])
 }
 return string(value), nil
}

// main function starts up the chaincode in the container during instantiate
func main() {
 if err := shim.Start(new(SimpleAsset)); err != nil {
 fmt.Printf("Error starting SimpleAsset chaincode: %s", err)
 }
}

```

## Building Chaincode

Now let's compile your chaincode.

```
go get -u github.com/hyperledger/fabric/core/chaincode/shim
go build
```

Assuming there are no errors, now we can proceed to the next step, testing your chaincode.

### 1.3. Testing Using dev mode

Normally chaincodes are started and maintained by peer. However in “dev mode”, chaincode is built and started by the user. This mode is useful during chaincode development phase for rapid code/build/run/debug cycle turnaround.

We start “dev mode” by leveraging pre-generated orderer and channel artifacts for a sample dev network. As such, the user can immediately jump into the process of compiling chaincode and driving calls.

## Install Hyperledger Fabric Samples

Navigate to the `chaincode-docker-devmode` directory of the `fabric-samples` clone:

```
cd chaincode-docker-devmode
```

Now open three terminals and navigate to your `chaincode-docker-devmode` directory in each.

### Terminal 1 - Start the network

Use the following command to start the network with the `SingleSampleMSPSolo` orderer profile and launch the peer in “dev mode”.

```
docker-compose -f docker-compose-simple.yaml up
```

The command also launches two additional containers - one for the chaincode environment and a CLI to interact with the chaincode. The commands for create and join channel are embedded in the CLI container, so we can jump immediately to the chaincode calls.

### Terminal 2 - Build & start the chaincode

Execute the following command in terminal 2:

```
docker exec -it chaincode bash
```

You should see the following:

```
root@d2629980e76b:/opt/gopath/src/chaincode#
```

Now, compile your chaincode:

```
cd sacc
go build
```

Now run the chaincode:

```
CORE_PEER_ADDRESS=peer:7052 CORE_CHAINCODE_ID_NAME=mycc:0 ./sacc
```

The chaincode is started with peer and chaincode logs indicating successful registration with the peer. Note that at this stage the chaincode is not associated with any channel. This is done in subsequent steps using the `instantiate` command.

## Terminal 3 - Use the chaincode

Even though you are in `--peer-chaincodedev` mode, you still have to install the chaincode so the life-cycle system chaincode can go through its checks normally. This requirement may be removed in the future when in `--peer-chaincodedev` mode.

We'll leverage the CLI container to drive these calls.

```
docker exec -it cli bash
peer chaincode install -p chaincodedev/chaincode/sacc -n mycc -v 0
peer chaincode instantiate -n mycc -v 0 -c '{"Args":["a","10"]}' -C myc
```

Now issue an invoke to change the value of "a" to "20".

```
peer chaincode invoke -n mycc -c '{"Args":["set", "a", "20"]}' -C myc
```

Finally, query `a`. We should see a value of `20`.

```
peer chaincode query -n mycc -c '{"Args":["query", "a"]}' -C myc
```

## 1.4. Testing new chaincode

By default, we mount only `sacc`. However, you can easily test different chaincodes by adding them to the `chaincode` subdirectory and relaunching your network. At this point they will be accessible in your `chaincode` container.

## 1.5. Chaincode encryption

In certain scenarios, it may be useful to encrypt values associated with a key in their entirety or simply in part. For example, if a person's social security number or address was being written to the ledger, then you likely would not want this data to appear in plaintext. Chaincode encryption is achieved by leveraging the `entities extension` which is a BCCSP wrapper with commodity factories and functions to perform cryptographic operations such as encryption and elliptic curve digital signatures. For example, to encrypt, the invoker of a chaincode passes in a cryptographic key via the transient field. The same key may then be used for subsequent query operations, allowing for proper decryption of the encrypted state values.

For more information and samples, see the `Enc Example` within the `fabric/examples` directory. Pay specific attention to the `utils.go` helper program. This utility loads the chaincode shim APIs and Entities extension and builds a new class of functions (e.g. `encryptAndPutState` & `getStateAndDecrypt`) that the sample encryption chaincode then leverages. As such, the chaincode can now marry the basic shim APIs of `Get` and `Put` with the added functionality of `Encrypt` and `Decrypt`.

## 1.6. Managing external dependencies for chaincode written in Go

If your chaincode requires packages not provided by the Go standard library, you will need to include those packages with your chaincode. There are [many tools available](#) for managing (or “vendoring”) these dependencies. The following demonstrates how to use `govendor`:

```
govendor init
govendor add +external // Add all external package, or
govendor add github.com/external/pkg // Add specific external package
```

This imports the external dependencies into a local `vendor` directory. `peer chaincode package` and `peer chaincode install` operations will then include code associated with the dependencies into the chaincode package.

---

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