NANYANG TECHNOLOGICAL UNIVERSITY

SCHOOL OF COMPUTER SCIENCE AND ENGINEERING

SCSE18-0141

Visual Formulation of Smart Contracts on Blockchains

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d Bac C Sc c

Abstract

T c c a a b d a d -d d a c ac d E b c c a . O , S a C ac B d , a a d c c b c c a , c a c . G a ca b c a d d a a a d c d a d c, c a c a c ac . T S a C ac B d a a a d a c ac c d b c c a c c ab . W a a a c a d a a a a c ac b a d c a a a a c ac . T d c a a d , c a ac d a d a c c .

Acknowledgements

T a A/P S a Sa a B c c a ca d da c a d .

T a d a d a c a a d c a , a d a c d a d da .

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1. Introduction

1.1 Bac d

A b c c a a - c d b d da aba a - - -a
c a a a ac a c ab a a d ac a d
a ac a d ac . E c c c a a 2008, a
a a a b d a a a c d c a .
D a a c a d c c a a , d d a a
a a c c a a ac .
B c c a a a d b a b d Sa
Na a 2008. T b c c a b c ad d a
c c d b d b d c a . [1]
W d d b c c a , a a
a d d c b c c a c d ac c a ,
a ca , a c , a a , , c ac a a a d .
N a 15% a c a a c b c c a c . I
2013, V a B , a a a c b B c c d ba , b ca
a d a a a d d a a ab b c c a .
M a c B c c , B b d c d
b c b c c a ca d E . T a d c b a
E ca c d a c a a c ac , c c .
B ca b c c a c a c , a a d
a , a d c a d . A a , b c c a
c a c d a da d a d
-d a . I d d b c c a ,
a a ca ca d S a C ac B d .
A a c ac c c d a a d a a
c ac a ca d a ac a a . T S a C ac B d
a ca a E a a c ac , a d

S d a a . W b a a ca a d c a
d b c c a , b -d .

1.2 Ob c a d Sc

T b c c c a a a ca ac a a
a b d a d -d c a a d d a c ac .
A b c c a a d a c ac a c c , b
ab d a c ac c d a c a d
a a c . B ab ac c d a a c a
b , b a c a b d b c c a ,
c a c a a a d c c a d a
c .
T c c c d a d a c ac
b a a c ac . B ca a ,
c a a . I , ca b d d
a a a a d b c c a .

1.3 E S

A , a a a ca ac a ca
ca d -d . C a d c a T
d c a a d d a c ac . H , a
a d a c d d a c ab c a d .
F , a d c , d a d
a c ac c d , d a ca a c d
. T a a c a M aMa c a ac
a c ac a d a a a , b d c c
b c a ca . T a a S a C ac B d
d c a Tab a B Da a V a a a d SAS da a c c a d
b a a c . H , c E a d b c c a a a

, a c c a b c c a

ab a d c a a a d acc b - c ca

.

2. Development and Implementation

2.1 S a A d T U d

2.1.1 R ac a d E c

I d b d S a C ac B d , E c a d R ac a
c .
E c a c a a a d c a b ac
a , a d ab d c a ac HTML a d
Ja aSc . W a E c a ca c d S ac ,
G H b a d M c V a S d C d . [2]
R ac a a - d a d d b Fac b a
b ac V a DOM. W a R ac
a : Fac b , I a a , N , W a a , Sa c , Ub , T N Y
T , CNN, D b , Da M , IMDB, V , a d R dd . [3]
E c R ac B a a d a ac a c . I
E c , R ac , R d , R ac R , W b ac a d R ac H L ad
a d a ca d (HMR). [4]

2.1.2 Add a ac a

I add , c c , Ga ac CLI a d b3 ac a a d. S c,
S d c , d c S d a c ac c d ac
adab c d . Ga ac CLI d a c b c c a b a
ab c a ca , a d W b3 d ac
b c c a d d a c ac a d ca c . Ga ac CLI
:// ca :8545 b d a .
Ma a -UI, a R ac b a a G a a d , a d
c a a a ca ac .

T S R ac D a a b a a a d d d a a d d
d a a c a d d b G a ca U l ac . T b a
a a d c d a a c a a a d
d a a d a a , a a b d ab
c a .

2.1.3 R IDE

R IDE a c a a d a c ac b .
W R IDE a c a a b a a a c ac
d c a a c a d c c a a a .

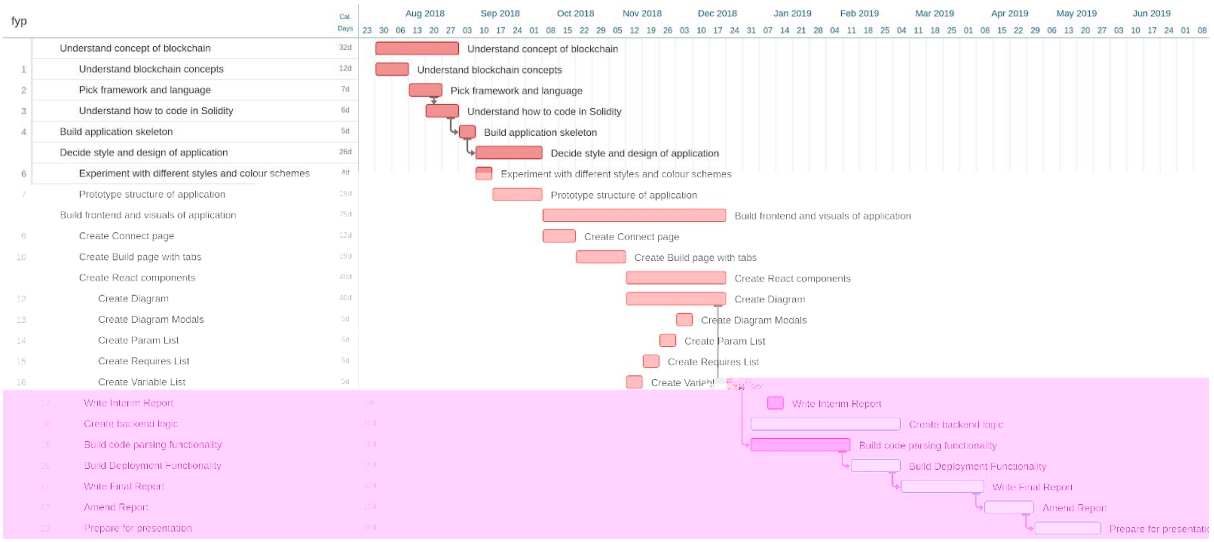
2.1.4 Ha d a

T a ca a b a a c 64 b L Ub 18.04,
8GB RAM a d a l (R) C (TM) 7-3770 CPU @ 3.40GH c . l
a a b d a W d ac 8GB RAM.

2.1.5 D d c

A d 1 d d c ac a . c .

2.2 P c Sc d



F 1.1: P c c d

T a a d a a a d a ca . B c c a a a ca , ab a a d d . W b d a a a c a c a a ab a d a ac . O c d a c d, c a d bac d c c c d a , c d a a d c d d . O c c d, ab c ac a d R IDE a d c a .

2.3 I a

I c , a acc c a ca d .

2.3.1 D

T d a ca a d d b a a d - da a b . I a a , a d d a ca a d d d a d a a a c a d c d d b

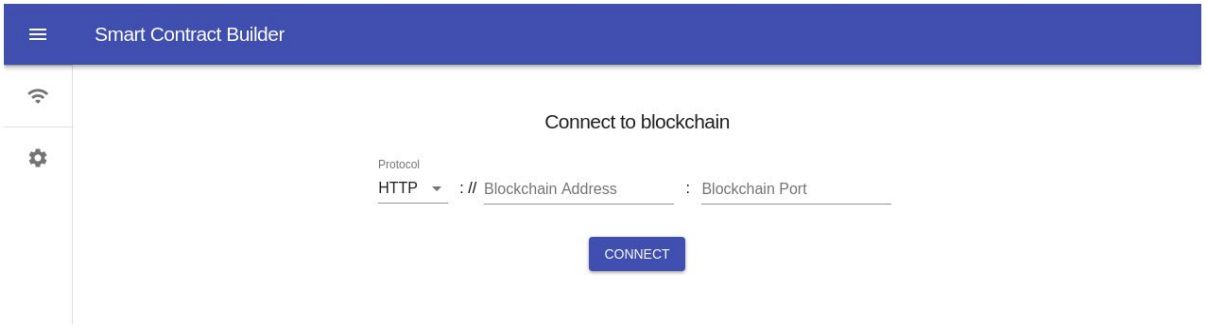
a a a d a da . W d a a d b c c a c b a c a d ca c a c a d c a a d c . [5]

T a c ac b d a 3 a c a d a :

c c a , G ba S a Tab a d B d Tab . T B d a a c a G ba S a Tab a d B d ab a a bac b c c c a , a a a b d b , c a d a c ac c d a d d .

2.3.1.1 C c Pa

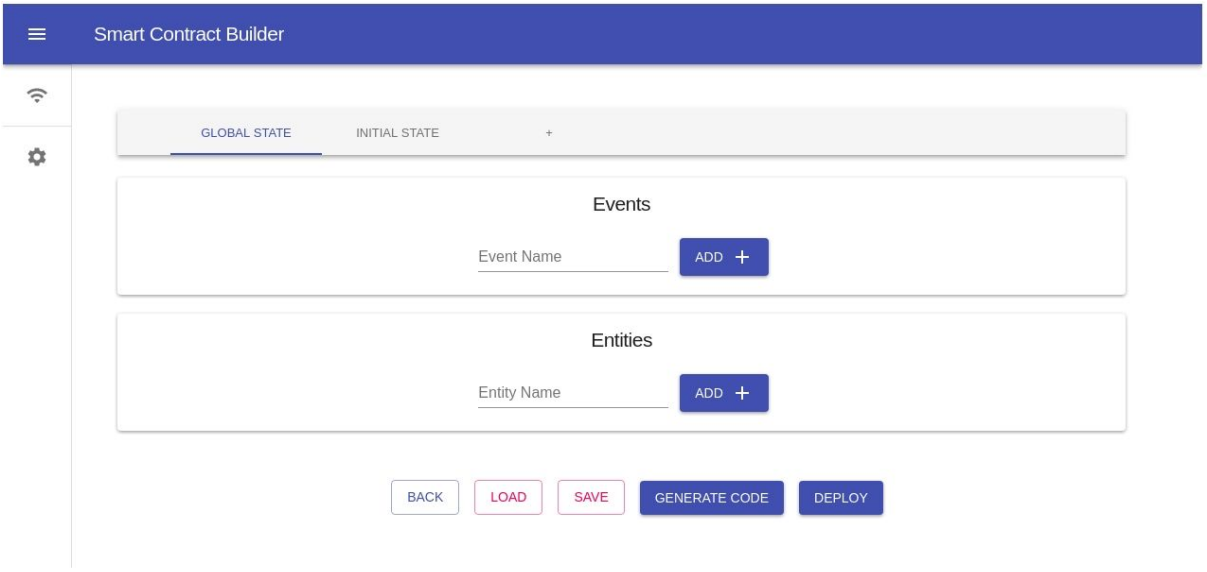
T a c ac b d a d a a c c c . U add a d b c c a d c c . F a , c c Ga ac CLI, add d b ca a d d b 8545, ba d d a Ga ac CLI . C c a a d b c c a b c d a , B d a , c c a G ba S a Tab a d B d Tab .



F 2.1: Sc C c Pa

2.3.1.2 G ba S a Tab

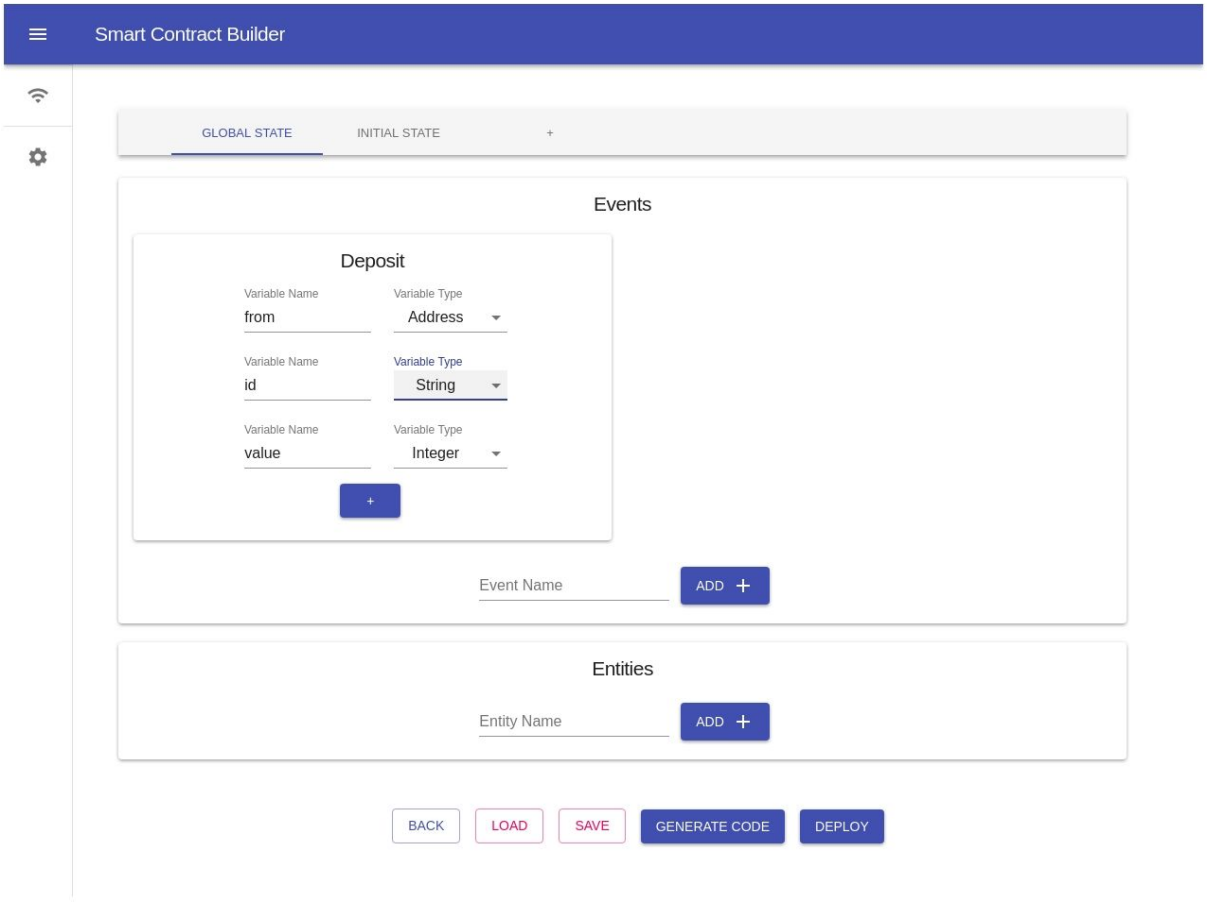
T G ba S a Tab d a a c ac a a d a c , a , a d c c a ab d c a a .



F 2.2: Sc G ba S a Tab

2.3.1.2.1 E B

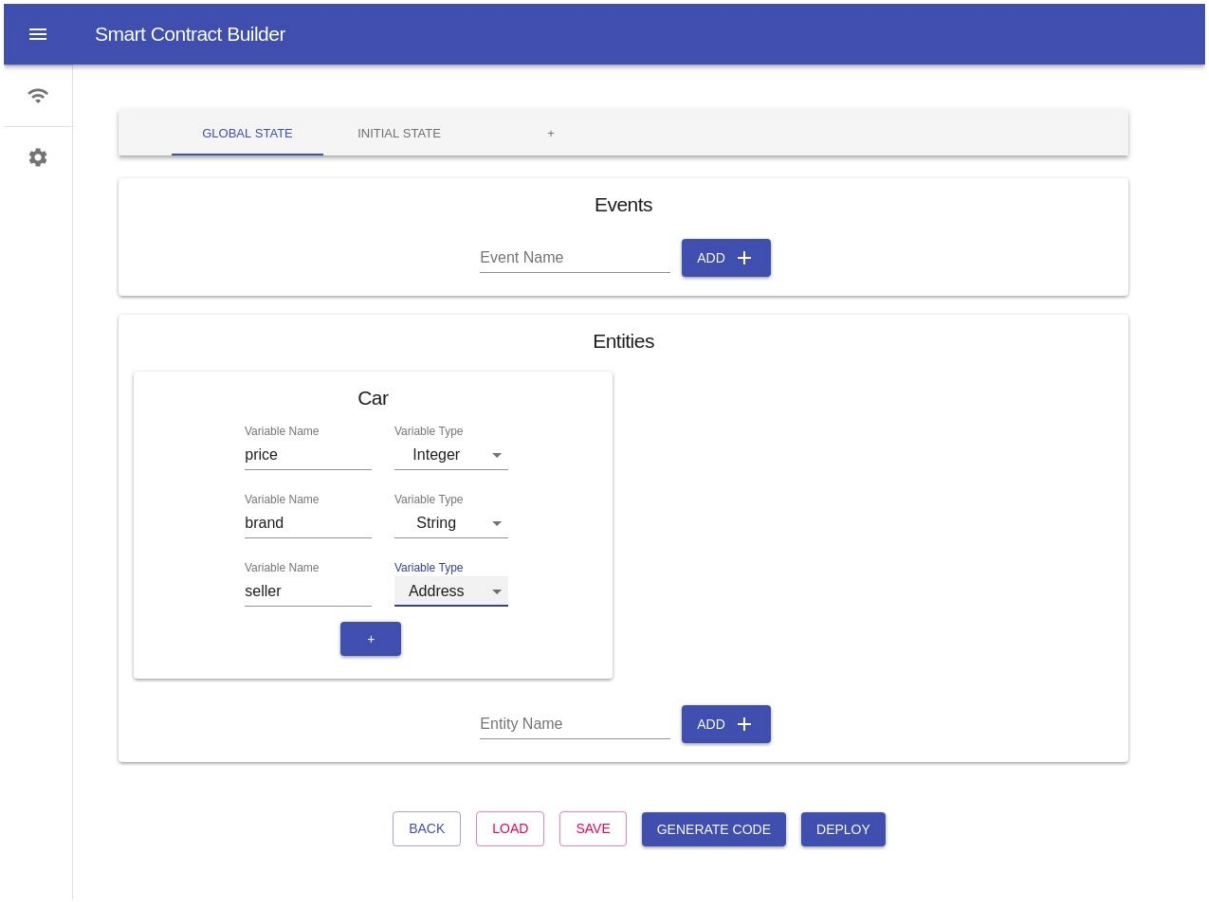
S d a ab ac EVM c a .
A ca ca b c b a d RPC ac
a E c .
E a ab b c ac . W ca , ca
a b d a ac - a c a da a c
b c c a . T a a c a d add c ac , a
c a d b c c a , a d a a a a b c acc b . [6]
I S a C ac B d , add b a a d
c c add b . T a a ab b a d ca add a d
c a a . T ca b d B d Tab .
A ab a b c d S c 2.3.1.3.3.



F 2.3: Sc a

2.3.1.2.2 E B

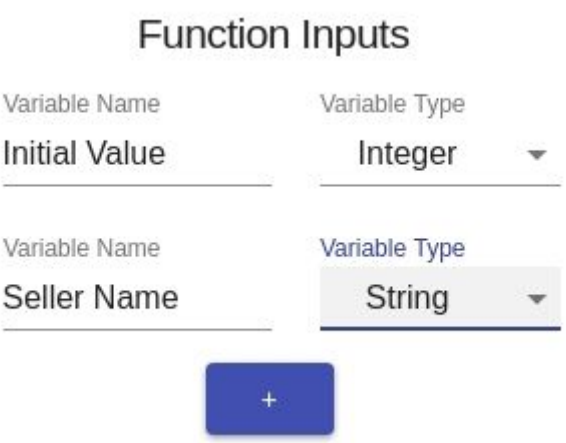
I S a C ac B d , c c a a a c S d a a C. E ca a a a b c c a c a a d ca c d . S a , a d c a d G ba S a Tab a ca b d a d a a B d Tab .



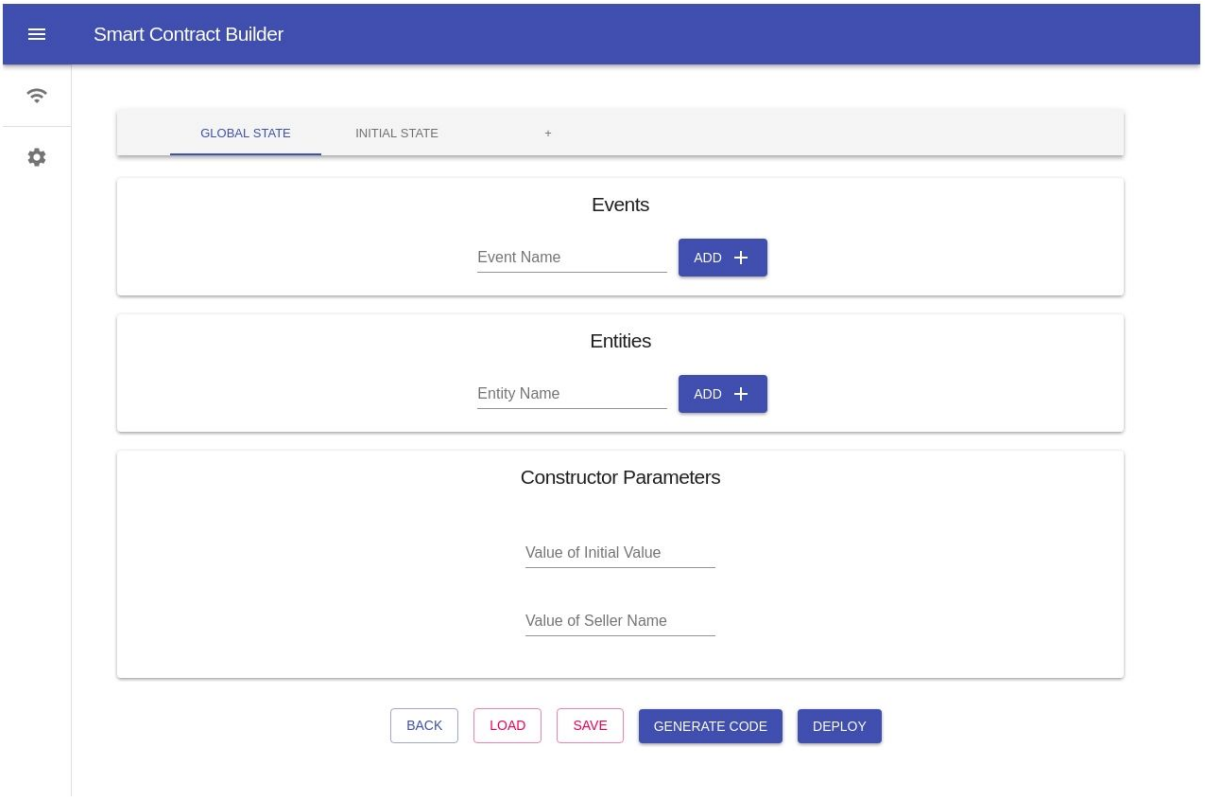
F 2.4: Sc a

2.3.1.2.3 C c Pa a B

T c c a a a b a d l a S a Tab, a d d b d G ba S a Tab. T a a c ac b a d c c a a a a . I c c d a a a a , c c a a d b d. F a , c c b l a S a Tab F 2.4, C c Pa a b a a a F 2.5:



F 2.5: I a S a Tab a

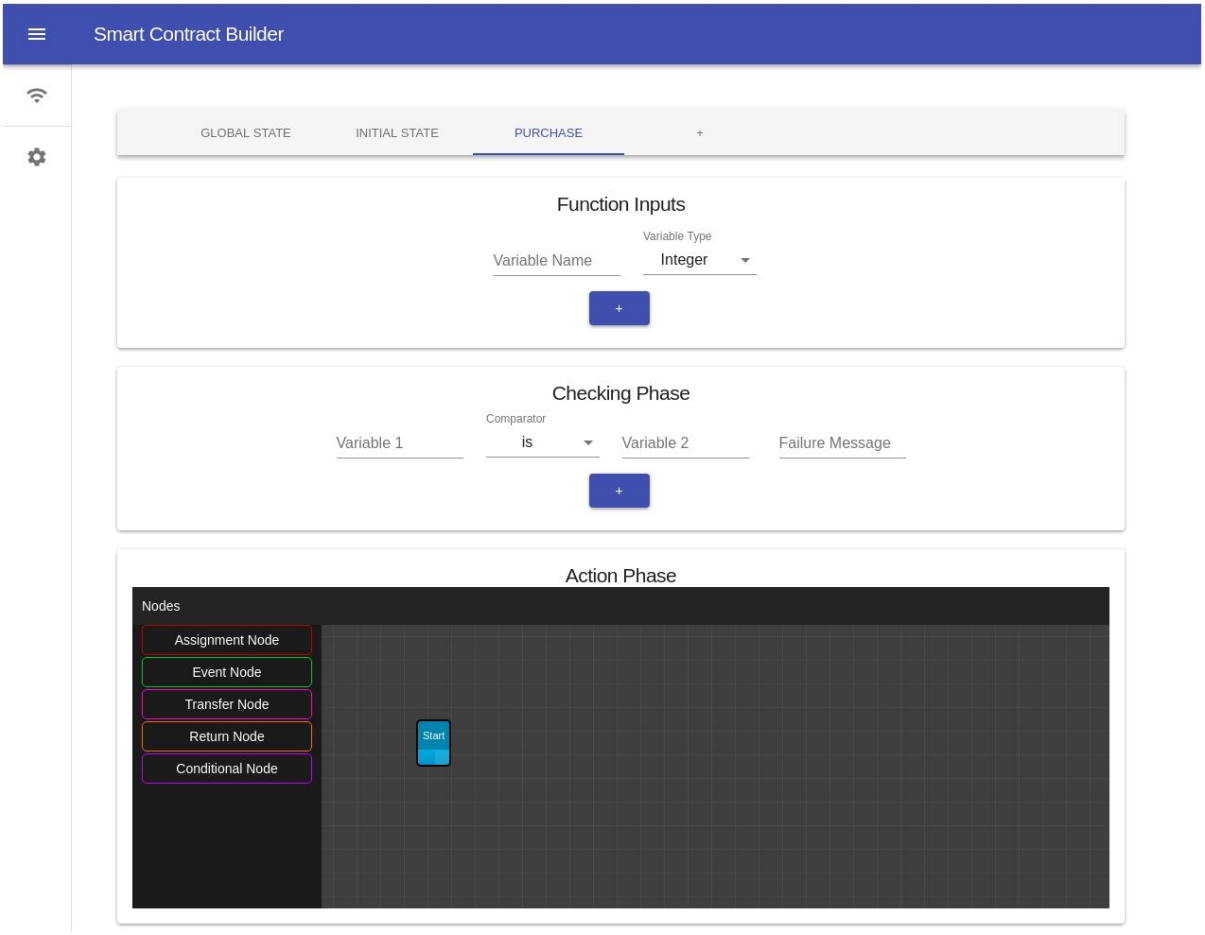


F 2.6: G ba S a Tab C c Pa a C d F 2.4

2.3.1.3 B d Tab

T B d Tab c a c ac . Eac c
c d B d Tab, a d c a a B d Tab.

T l a S a Tab c c c , add a c ca b add d b c c a d a -d ca a . T a 3 b a B d Tab: c b , c c a a d ac a .



F 2.7: E a P c a B d Tab

2.3.1.3.1 F c l B 4

T c b a c c a a ac c a a . C c b add a add a c a a .

2.3.1.3.2 C c P a B

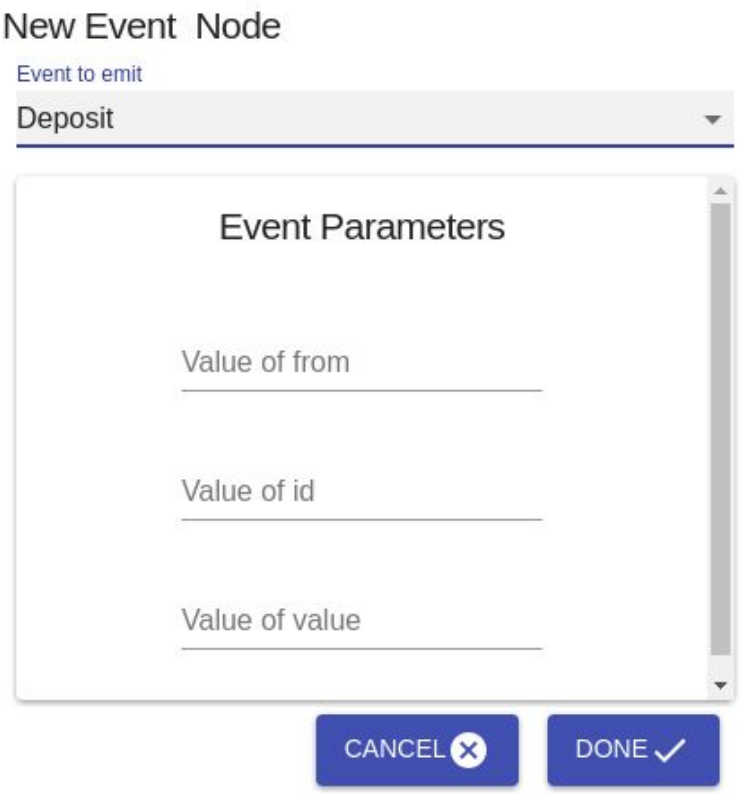
T c c a a d b a c . I c d c d a , a ac a d b c c a b d

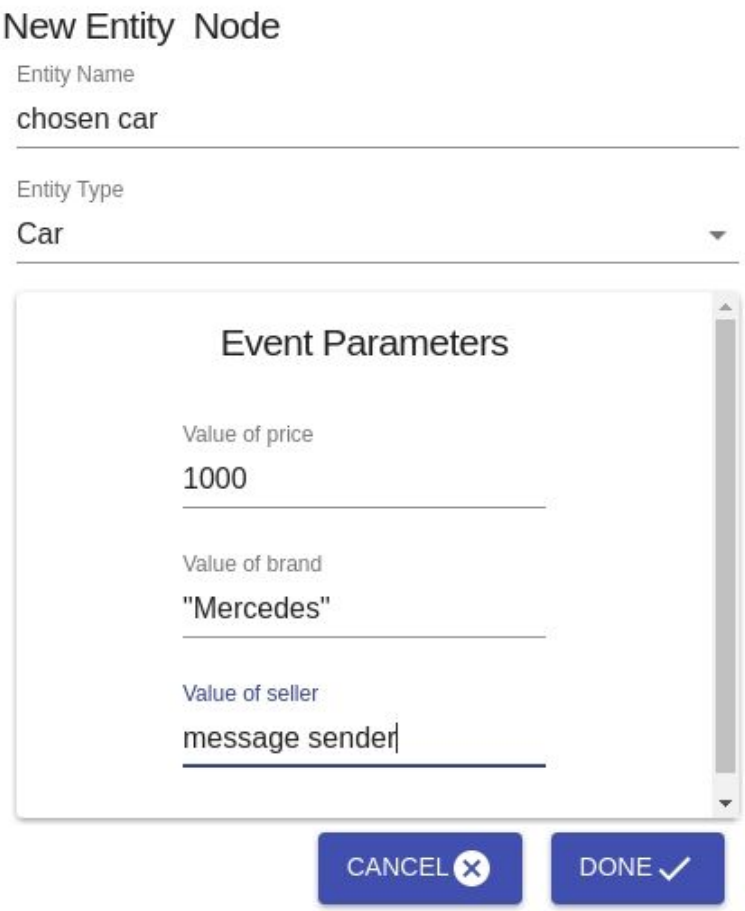
b c a .T a a b d a d b a
c ac c d .

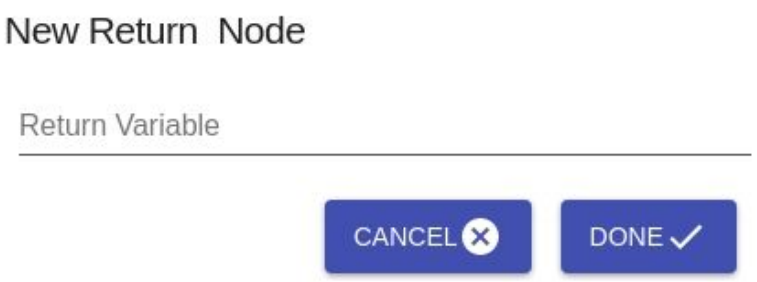
2.3.1.3.3 Ac P a B

T ac a ac a c a b a a d c d , a d
a d a a d a a d d d a a .T c a d a
a add d a a a , a d d a a d d
d a a .A da b d a d a a d c
da a d c c d b , d b add d d a a .
T c c d ca d c .
T ab da ac d :

N d	M da
A N d	

E N d	 New Event Node Event to emit Deposit Event Parameters Value of from Value of id Value of value CANCEL DONE

E N d	 New Entity Node Entity Name chosen car Entity Type Car Event Parameters Value of price 1000 Value of brand "Mercedes" Value of seller message sender CANCEL DONE
T a N d	 New Transfer Node Transfer to Value CANCEL DONE

R N d	
C d a N d	

Tab 2.1: M da a a a c a d a d

N a a d d , a d a a d d a d d G ba S a Tab. I Tab 2.1, a d F 2.3. A a ab d a . T a d c a a ab a d a ab d c a , a bac d c a d (a c 2.4). O a d ad d c a a a ab a a d G ba S a Tab, b d c d d a a d ab ac c c a ab a c a b .

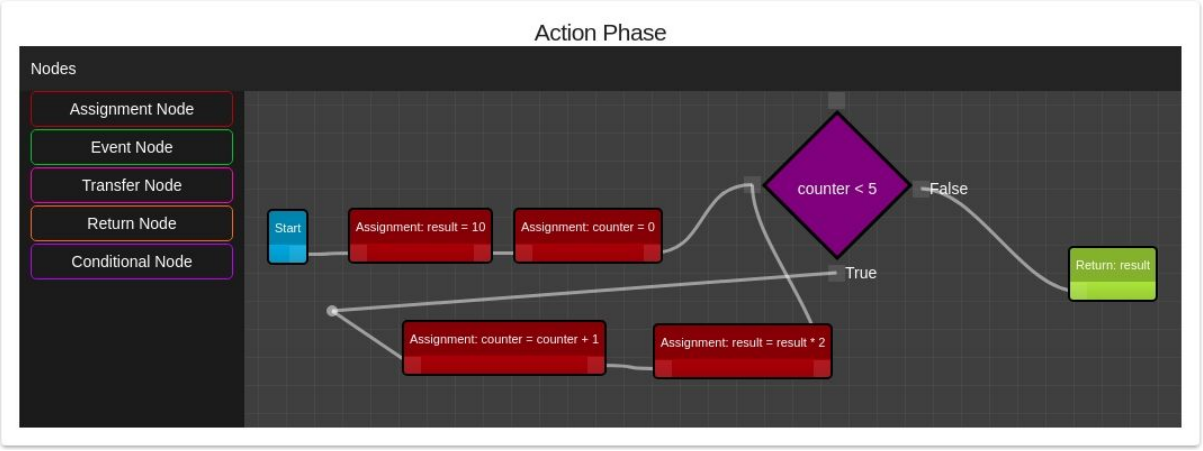
2.3.2 Bac d L c

T a 2 a c b bac d c: B dPa c a a d B dO c . T a a a a d ad c a , a a a d c .

2.3.2.1 B dPa

T B dPa b a d a a a d a c d ac c . A a c B dPa c a a ac d ac a c Ac P a d a a . A U da d a ac d ac d a a , a d B dPa a d ca d a c a d b 2 d ,. T B dPa ac c d a d a d , c d d c d c a a . T B dPa a d a a 2 . T a ab , a d add a a d a a ab ab . I c c A , N E a d T a d a d d a ab a ab . I c d , B dPa a ac d c a d d a a , a d ac b . A ac d , a a a ab d a d a Va ab d a d a c d a d a N d d. I a ab ab a ac a a ab a ca a d , a c c b . I d a d , a da a ab c d c a a .

W c a c d a d , c a 2 c c d b a d a c d , a ac a a a a d c d . I a , a F 2.8, d c a c c d a a a d a d a a c ac c d ad a a . A , d c a c a d a a , c d a d a a a a .



F 2.8: E a d c d d c c

T a a d a a d a a , b a d a b a a d d a ab a ab d a ad d . I a a d a ab a d a c d a d a a , c d c d b . A a d 2 ad 1, a ab a a a a ab a d a c d .

S c a 2 a a a ab a d a c d a d d ac a d ac c , a a a c O(2) = O( ) b d d a a . T a b d d a a a c c d a d .

2.3.2.2 B dO

T B dO R ac c b a c d a d d b c c a . I d c c B d b a b B d a . I a d a a d c d a d I a S a Tab a d B d Tab , a d a a ac ca c c S d a c ac . I b3 a d a c ac . I a a d, b d. I d cc , a ac a

a c ac b . T a ac a ca b d c c a a ac b c c a .

2.3.2.2.1 C d G a

Eac d c ca b b d , c c d ac c a b . A d 2 a c a ca d c ac a d c .

B d c a a c ac , a ab ac a b a c c . T a a a a a a a c ac .

W a c d b c c d, b a d a -d d S d a d_c ac d c . T a c a d c b d a S c 2.3.2.2.3.

2.3.2.2.2 C ac C a a d D

B ca c b a a bac d a c a d d d , c c a b d bac d, a a a c . B cR d a d cMa c a , a ab d a a ad c d c d ac adab a ca b a ac (ABI). T C ac A ca B a I ac (ABI) a da d a ac c ac E c , b d b c c a a d c ac - -c ac ac . [7] A c a , b3 b d d c ac b c c a .

2.3.2.2.3 Sa a d L ad M c a

T S a C ac B d ab a c a d ad a a a . T ac d E c add , adF a d F c d ( ). T a d a d_da a d c . T add c ad a a d_da a d c a d

a . W a b c c d, a a a
a a . A a a , a
B d c , a a d c a I a S a Tab a d
B d Tab , b d a d d d a JSON
a ca d c . W ad b c c d, a a a
c c JSON ad. T JSON b ad a d a d, a d
a B d c b d c JSON .

3. Evaluation of Results

3.1 M d a a

T a a c a d c c a ca ,
a a c d d a d c a c ac .
Ga a a a a c a a a a
c c a a . E a a a E , b
a a ac , a a c ac , a ICO a a a .
Ga a d ca c a a a d b a d
d c a a . [8]
W b a d a a a S d a c ac c a S d
d c a [9] a d d d S a C ac B d ac
a c a . W a b a a d a d a c ac
R IDE, c a , c a a
S d c ac a b . R d a a
b , c d a a c a . F b c ac , d a
Ja a c VM a d.

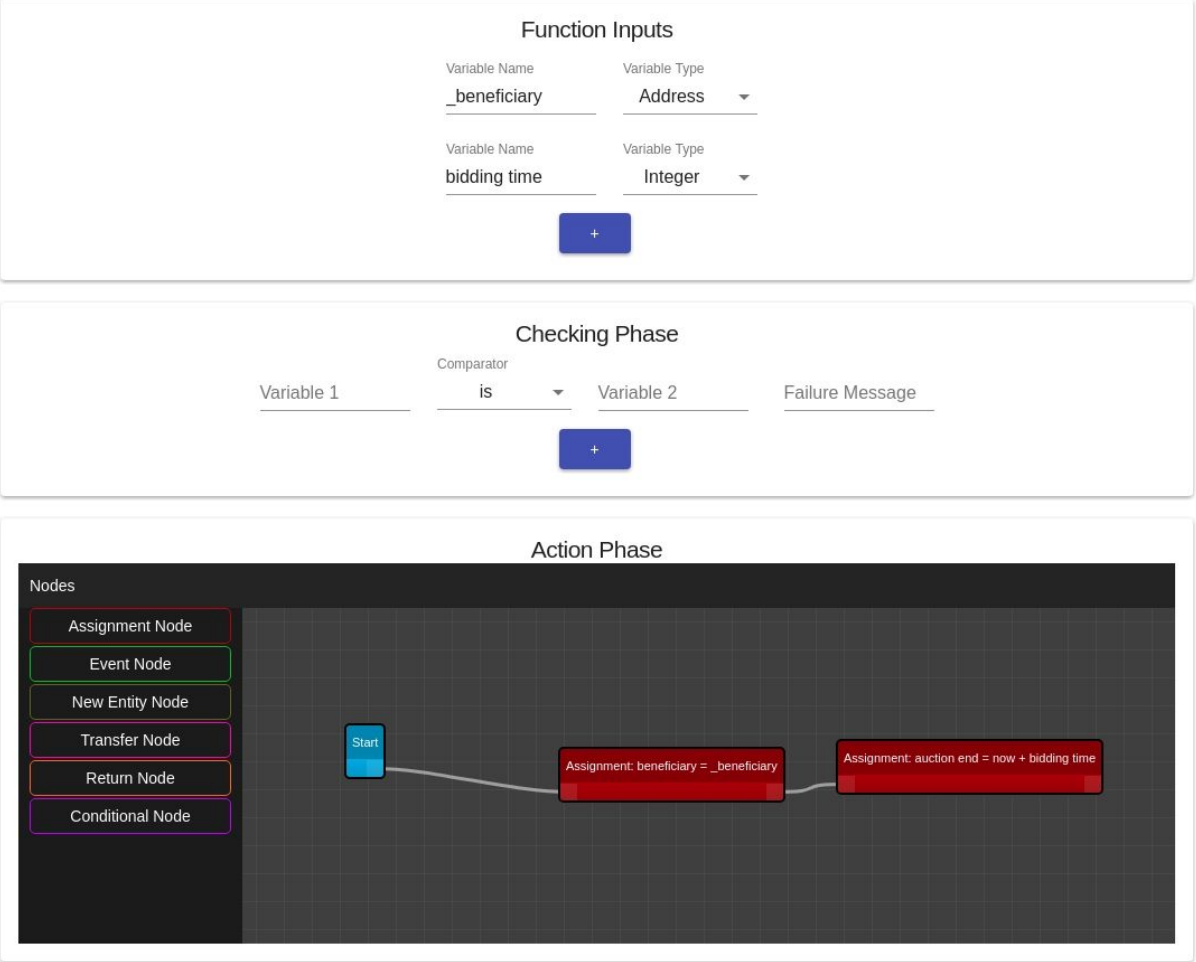
3.2 R

T a a :

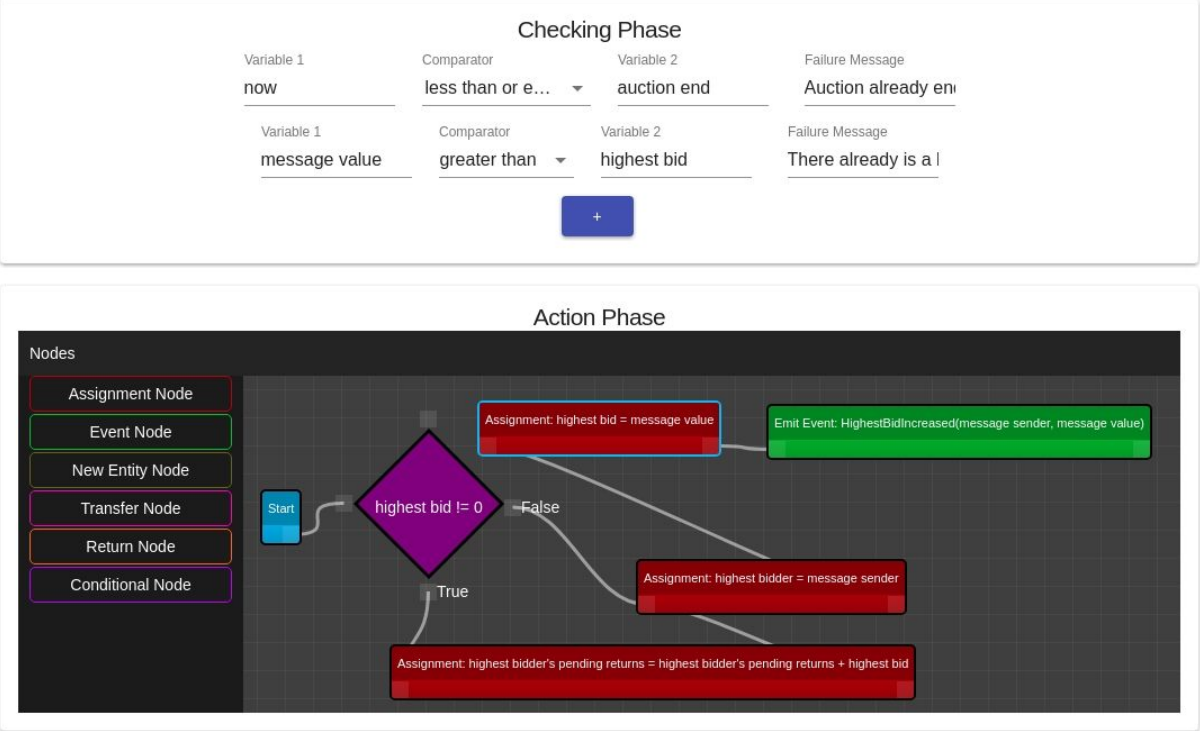
	O _a c . D c a	S a C ac B d	P a c D c
D c	400000 a	422800 a	-5.7%
C c c	440866 a	463667 a	-5.17%
B d c	63208 a	63543 a	-0.53%
W d a c			-
A c d d c			-

Tab 3.1: C a a c c c ac

T c d _a c . a d c d a d a c ac b d ca b d A d c 3 a d 4 c . F 3.1 a d 3.2 B d Tab c c a d b d c c .



F 3.1: C c F c



F 3.2: B d F c

U a , R IDE a c a a ab b a a a d a a d a c d d c , a d a a b c c ac a d a d c ac .

D c a ba d c d da a b c c a . T a 4 c a a ac c :

ba c a a ac (21000 a)

c a c ac d (32000 a)

c b da a c d a a ac .

c - b da a c d a a ac .

E c c a ba d c c a a a c a c d a a a ac .

F ab 3.1, ca a d c 5.7% a d c ac , c c c c c 5.17% a d c ac , a d c c b d c 0.53% . T a c d d a ca c c ac , b b ca a a a , c ac . F a a c ac , 5%

d c b a ca . H , c c d
a ca a d, d a acc ab a d d c
ca . T a a d c d a a ca b d
a c c a d a a .

4. Conclusions

I c, a a c a a , - d a ca a a d b d a d -d c a a c ac a d d a .T a c a c a a ac a a c a a d , bac d c d a b c d a a a d, c a a ab a d d a a .

F , ca a a c, S a C ac B d ab a a d c a c ac, b d c a d ac a a - c d, ca c c c a d d c ac, a Tab 3.1. T a a a a c ac d c a , a a a c d a a c a c ac. M a b d a d a a c ac d a a b ad c ca d a .F , S a C ac B d a c a d a a d c d a a d c .

N , S a C ac B d c d ac a a c, b a d c a d b c c a .

D a S a C ac B d a a a c ac, a d a a .U a d b c c a b d a c ca - ca S a C ac B d a a a a c ac a.

5. Recommendations

T c ab , c a ab ac
c d a a a c ca b d b d c a
a a a a a a c a ca d c b
a a c ac d d ad c. T d a a ca b
a d d c , c a a a .
F , ac d b c c a a d E ,
a d a d c a , a ca a b c da d
S d d c da . C a d d
a ca da S d a da d . I a b b a S d
b c b a E a d c d V , a
a c ac a a . [10] F d b d a
a ca d . C a b a c ac
a a V ca b d c d a a b a d
. I add , c a b d B c c a
H d Fab c ca a b d c d a a a c a a d c ca
b ac d.

6. End Section

6.1 A d c

```
"devDependencies": {
   "babel-core": "^6.26.3",
   "babel-eslint": "^8.2.6",
   "babel-jest": "^23.4.2",
   "babel-loader": "^7.1.5",
   "babel-plugin-add-module-exports": "^0.2.1",
   "babel-plugin-dev-expression": "^0.2.1",
   "babel-plugin-flow-runtime": "^0.17.0",
   "babel-plugin-transform-class-properties": "^6.24.1",
   "babel-plugin-transform-es2015-classes": "^6.24.1",
   "babel-preset-env": "^1.7.0",
   "babel-preset-react": "^6.24.1",
   "babel-preset-react-optimize": "^1.0.1",
   "babel-preset-stage-0": "^6.24.1",
   "babel-register": "^6.26.0",
   "chalk": "^2.4.1",
   "concurrently": "^3.6.1",
   "cross-env": "^5.2.0",
   "cross-spawn": "^6.0.5",
   "css-loader": "^1.0.0",
   "detect-port": "^1.2.3",
   "electron": "^2.0.6",
   "electron-builder": "^20.26.0",
   "electron-devtools-installer": "^2.2.4",
   "electron-rebuild": "^1.8.2",
   "enzyme": "^3.3.0",
   "enzyme-adapter-react-16": "^1.1.1",
```

```
  "enzyme-to-json": "^3.3.4",
  "eslint": "^5.2.0",
  "eslint-config-airbnb": "^17.0.0",
  "eslint-config-prettier": "^2.9.0",
  "eslint-formatter-pretty": "^1.3.0",
  "eslint-import-resolver-webpack": "^0.10.1",
  "eslint-plugin-compat": "^2.5.1",
  "eslint-plugin-flowtype": "^2.50.0",
  "eslint-plugin-import": "^2.13.0",
  "eslint-plugin-jest": "^21.18.0",
  "eslint-plugin-jsx-a11y": "6.1.1",
  "eslint-plugin-promise": "^3.8.0",
  "eslint-plugin-react": "^7.10.0",
  "express": "^4.16.3",
  "fbjs-scripts": "^0.8.3",
  "file-loader": "^1.1.11",
  "flow-bin": "^0.77.0",
  "flow-runtime": "^0.17.0",
  "flow-typed": "^2.5.1",
  "husky": "^0.14.3",
  "identity-obj-proxy": "^3.0.0",
  "jest": "^23.4.2",
  "lint-staged": "^7.2.0",
  "mini-css-extract-plugin": "^0.4.1",
  "minimist": "^1.2.0",
  "node-sass": "^4.9.2",
  "npm-logical-tree": "^1.2.1",
  "optimize-css-assets-webpack-plugin": "^5.0.0",
  "prettier": "^1.14.0",
  "react-test-renderer": "^16.4.1",
  "redux-logger": "^3.0.6",
```

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    "sass-loader": "^7.0.3",
    "sinon": "^6.1.4",
    "spectron": "^3.8.0",
    "storm-react-diagrams": "^5.2.1",
    "style-loader": "^0.21.0",
    "stylelint": "^9.4.0",
    "stylelint-config-standard": "^18.2.0",
    "uglifyjs-webpack-plugin": "1.2.7",
    "url-loader": "^1.0.1",
    "webpack": "^4.16.3",
    "webpack-bundle-analyzer": "^2.13.1",
    "webpack-cli": "^3.1.0",
    "webpack-dev-server": "^3.1.5",
    "webpack-merge": "^4.1.3",
    "yarn": "^1.9.2"
  },
  "dependencies": {
    "@fortawesome/fontawesome-free": "^5.2.0",
    "@material-ui/core": "^3.0.1",
    "@material-ui/icons": "^3.0.1",
    "devtron": "^1.4.0",
    "electron-debug": "^2.0.0",
    "history": "^4.7.2",
    "react": "^16.4.1",
    "react-dom": "^16.4.1",
    "react-hot-loader": "^4.3.4",
    "react-redux": "^5.0.7",
    "react-router": "^4.3.1",
    "react-router-dom": "^4.3.1",
    "react-router-redux": "^5.0.0-alpha.6",
```

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    "redux": "^4.0.0",
    "redux-thunk": "^2.3.0",
    "source-map-support": "^0.5.6",
    "typeface-roboto": "0.0.54",
    "web3": "^1.0.0-beta.35"
  },
  "devEngines": {
    "node": ">=7.x",
    "npm": ">=4.x",
    "yarn": ">=0.21.3"
  }
```

A d 1: ac a . d d c

```
pragma solidity ^0.5.4;

contract {contract name} {
    /// variable declarations
    {variable_type} public {variable_name}
    uint public value;
    address public seller;
    address public buyer;

    constructor() public payable {
       {constructor code}
    }

    event {event_name} ({parameter_type} {parameter_name})
    event Aborted();
    event PurchaseConfirmed();
    event ItemReceived();
```

```
    /// returns does not appear if there is no return statement
function {function_name}({function_params}) public returns (int) {
        {require_statements}
        {function_code}
    }

    function abort() public
    {
        emit Aborted();
        seller.transfer(address(this).balance);
    }

    function confirmPurchase() public payable
    {
        emit PurchaseConfirmed();
        buyer = msg.sender;
    }

    function confirmReceived() public
    {
        emit ItemReceived();
        buyer.transfer(value);
        seller.transfer(address(this).balance);
    }
}
```

A d 2: S c a S d a c ac

```
pragma solidity >=0.4.22 <0.6.0;

contract SimpleAuction {
   // Parameters of the auction. Times are either
   // absolute unix timestamps (seconds since 1970-01-01)
   // or time periods in seconds.
```

```
    address payable public beneficiary;
    uint public auctionEndTime;

    // Current state of the auction.
    address public highestBidder;
    uint public highestBid;

    // Allowed withdrawals of previous bids
    mapping(address => uint) pendingReturns;

    // Set to true at the end, disallows any change.
    // By default initialized to `false`.
    bool ended;

    // Events that will be emitted on changes.
    event HighestBidIncreased(address bidder, uint amount);
    event AuctionEnded(address winner, uint amount);

    // The following is a so-called natspec comment,
    // recognizable by the three slashes.
    // It will be shown when the user is asked to
    // confirm a transaction.

    /// Create a simple auction with `_biddingTime`
    /// seconds bidding time on behalf of the
    /// beneficiary address `_beneficiary`.
    constructor(
        uint _biddingTime,
        address payable _beneficiary
    ) public {
        beneficiary = _beneficiary;
        auctionEndTime = now + _biddingTime;
    }

    /// Bid on the auction with the value sent
    /// together with this transaction.
    /// The value will only be refunded if the
    /// auction is not won.
    function bid() public payable {
        // No arguments are necessary, all
        // information is already part of
```

```
        // the transaction. The keyword payable
        // is required for the function to
        // be able to receive Ether.

        // Revert the call if the bidding
        // period is over.
        require(
            now <= auctionEndTime,
            "Auction already ended."
        );

        // If the bid is not higher, send the
        // money back.
        require(
            msg.value > highestBid,
            "There already is a higher bid."
        );

        if (highestBid != 0) {
            // Sending back the money by simply using
            // highestBidder.send(highestBid) is a security risk
            // because it could execute an untrusted contract.
            // It is always safer to let the recipients
            // withdraw their money themselves.
            pendingReturns[highestBidder] += highestBid;
        }
        highestBidder = msg.sender;
        highestBid = msg.value;
        emit HighestBidIncreased(msg.sender, msg.value);
    }

    /// Withdraw a bid that was overbid.
    function withdraw() public returns (bool) {
        uint amount = pendingReturns[msg.sender];
        if (amount > 0) {
            // It is important to set this to zero because the
recipient
            // can call this function again as part of the
receiving call
            // before `send` returns.
            pendingReturns[msg.sender] = 0;
```

```
            if (!msg.sender.send(amount)) {
                // No need to call throw here, just reset the
amount owing
                pendingReturns[msg.sender] = amount;
                return false;
            }
        }
        return true;
    }

    /// End the auction and send the highest bid
    /// to the beneficiary.
    function auctionEnd() public {
        // It is a good guideline to structure functions that
interact
        // with other contracts (i.e. they call functions or send
Ether)
        // into three phases:
        // 1. checking conditions
        // 2. performing actions (potentially changing conditions)
        // 3. interacting with other contracts
        // If these phases are mixed up, the other contract could
call
        // back into the current contract and modify the state or
cause
        // effects (ether payout) to be performed multiple times.
        // If functions called internally include interaction with
external
        // contracts, they also have to be considered interaction
with
        // external contracts.

        // 1. Conditions
        require(now >= auctionEndTime, "Auction not yet ended.");
        require(!ended, "auctionEnd has already been called.");

        // 2. Effects
        ended = true;
        emit AuctionEnded(highestBidder, highestBid);
```

```
        // 3. Interaction
        beneficiary.transfer(highestBid);
    }
}
```

A d 3: _a c . S d d c a

```
pragma solidity ^0.5.4;
contract Code {
bool public ended;
uint public amount;
mapping(address => uint) pending_returns;
address payable public highest_bidder;
uint public highest_bid;
address payable public beneficiary;
uint public auction_end;
event HighestBidIncreased (address payable bidder, uint amount);
event AuctionEnded (address payable winner, uint amount);
constructor(address payable _beneficiary, uint bidding_time)
public payable  {
      beneficiary = _beneficiary;
auction_end = now + bidding_time;
}
function bid() public payable  {
      require(now <= auction_end, "Auction already ended.");
require(msg.value > highest_bid, "There already is a higher
bid.");
if (highest_bid != 0) {
pending_returns[highest_bidder] = pending_returns[highest_bidder]
+ highest_bid;
}
highest_bidder = msg.sender;
highest_bid = msg.value;
emit HighestBidIncreased(msg.sender, msg.value);
}
function withdraw() public payable  {
      amount = pending_returns[msg.sender];
if (amount > 0) {
pending_returns[msg.sender] = 0;
msg.sender.transfer(amount);
}
```

```
}
function auctionEnd() public payable  {
      require(now >= auction_end, "Auction not yet ended.");
require(ended == false, "auctionEnd has already been called.");
ended = true;
emit AuctionEnded(highest_bidder, highest_bid);
beneficiary.transfer(highest_bid);
}
}
```

A d 4: C d a d b S a C ac B d

6.2 R c

[1] F b .c . (2019). A V B H O B c c a T c E S d R ad. [ ] A a ab a : :// . b .c / /b a d a /2018/02/16/a- -b - - -b c c a - c - - d- ad/#79c719 97bc4 [Acc d 18 F b. 2019].

[2] H -T G . (2019). W a A E c A , a d W Ha T B c S C ?. [ ] A a ab a : :// . .c /330493/ a -a - c -a -a d- - a - -b c - -c / [Acc d 18 F b. 2019].

[3] M d . (2019). Ad a a D M d W b a R ac . . [ ] A a ab a : :// d .c /@ a a a d/ad a a - -d - d - b-a - - ac - -8504c571db71 [Acc d 18 F b. 2019].

[4] G H b. (2019). c - ac -b a / c - ac -b a . [ ] A a ab a : :// b.c / c - ac -b a / c - ac -b a [Acc d 18 F b. 2019].

[5] Ca , J. (2019). W b d c : c a c b d . [ ] T N W b. A a ab a : :// b.c /dd/2015/04/07/ - -c a - - - - -c - - b-d / [Acc d 18 F b. 2019].

[6] S d . ad d c . . (2019). C ac S d 0.5.3 d c a .

[ ] A a ab a : :// d . ad d c . / / 0.5.3/c ac .
[Acc d 18 F b. 2019]. 7
[7] S d . ad d c . . (2019). C ac ABI S c ca S d 0.5.3
d c a . [ ] A a ab a :
:// d . ad d c . / / 0.5.3/ab - c. [Acc d 18 F b. 2019].
[8] B c .c . (2019). [ ] A a ab a :
://b c .c / d / - a - -b - - d / [Acc d 18 F b.
2019]. 7
[9] S d . ad d c . . (2019). S d b E a S d 0.5.5
d c a . [ ] A a ab a :
:// d . ad d c . / / a / d -b - a . # - -a c
[Acc d 1 Ma . 2019].
[10] B c .c . (2019). [ ] A a ab a :
://b c .c / d / - / [Acc d 18 F b. 2019].