以太坊区块链网络部署及验证实验

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0. 实验目标

通过部署一个包含至少4个节点的以太坊私有区块链网络，掌握以太坊私链的搭建、节点间通信、挖矿机制以及智能合约的部署与调用方法，从而深入理解区块链网络的基本原理和操作流程

1. 环境搭建

- 基础系统：WSL2 搭载 Ubuntu 20.04.6 LTS
- 编译环境：Golang 1.19，为 Geth 客户端提供编译与运行支持
- 以太坊客户端：Geth 1.10.25，用于搭建和管理私有区块链网络

1.1. Go 1.19安装

1. **下载 Go (v1.19)**

```
wget https://dl.google.com/go/go1.19.linux-amd64.tar.gz
```

2. **解压文件**

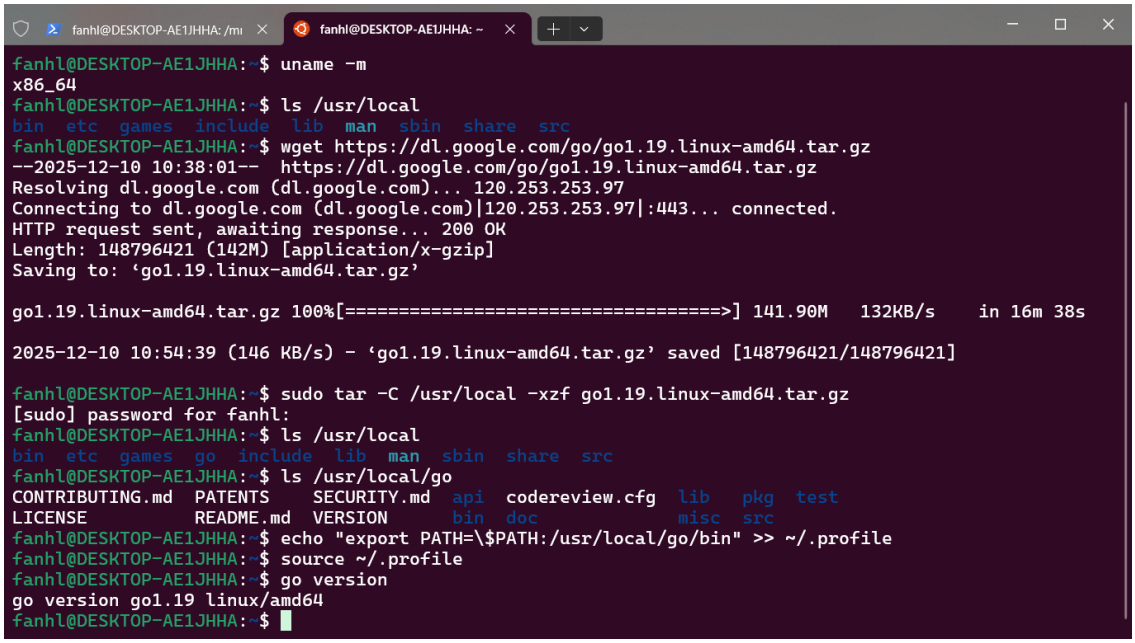
```
sudo tar -C /usr/local -xzf go1.19.linux-amd64.tar.gz
```

3. **设置环境变量**

```
echo "export PATH=\$PATH:/usr/local/go/bin" >> ~/.profile
```

4. **使更改生效**

```
source ~/.profile
```



1.2. Geth 1.10.25 安装

1. **下载 Geth (v1.10.25)**

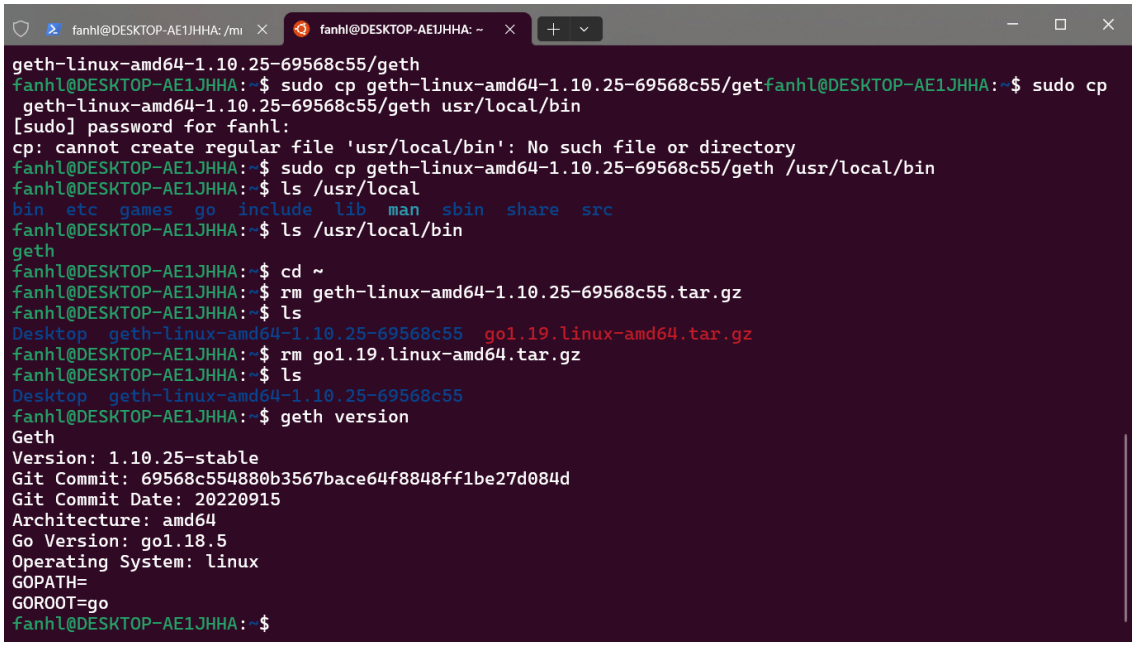
```
wget https://gethstore.blob.core.windows.net/builds/geth-linux-amd64-1.10.25-69568c55.tar.gz
```

2. **解压文件**

```
tar -xvzf geth-linux-amd64-1.10.25-69568c55.tar.gz
```

3. **移动 Geth 到可执行目录**

```
sudo mv geth-linux-amd64-1.10.25-69568c55/geth /usr/local/bin/
```



2. 网络部署

2.1. 创世区块配置

- **自定义文件目录结构说明**

```
/home/fanhl/ethdata/     # 实验文件夹
├── genesis.json         # 创世区块信息文件
├── node1/               # 节点1数据目录
├── node2/               # 节点2数据目录
├── node3/               # 节点3数据目录
├── node4/               # 节点4数据目录
└── logs/                # 节点运行日志
```

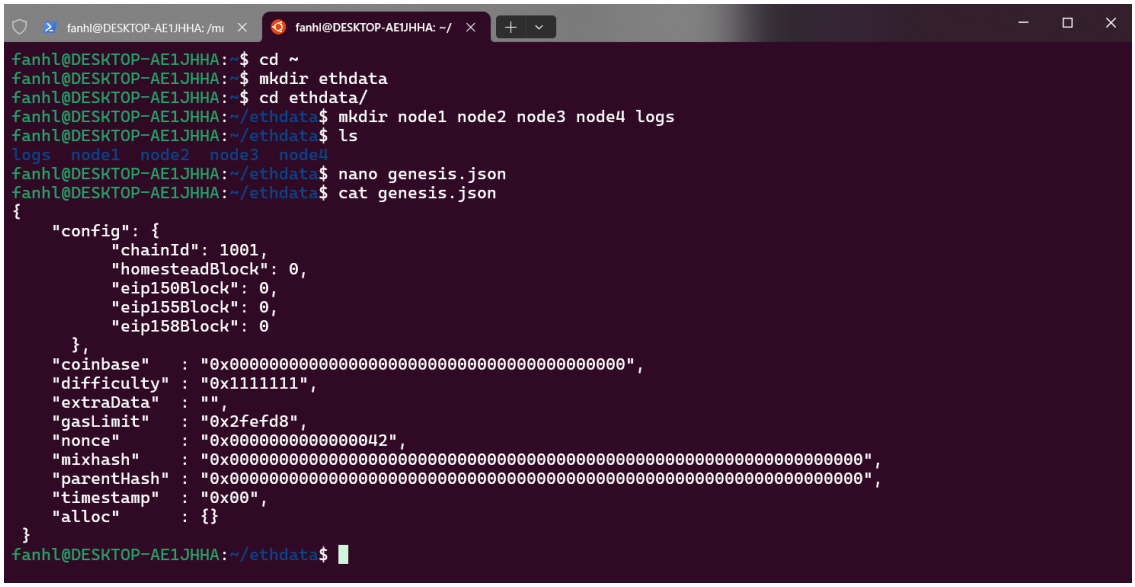
- **添加创世区块配置文件**

```
nano genesis.json
```

```
{
    "config": {
          "chainId": 1001,
          "homesteadBlock": 0,
          "eip150Block": 0,
          "eip155Block": 0,
          "eip158Block": 0
      },
    "coinbase"   : "0x0000000000000000000000000000000000000000",
    "difficulty" : "0x1111111",
    "extraData"  : "",
    "gasLimit"   : "0x2fefd8",
    "nonce"      : "0x0000000000000042",
    "mixhash"    :
"0x0000000000000000000000000000000000000000000000000000000000000000",
    "parentHash" :
"0x0000000000000000000000000000000000000000000000000000000000000000",
  "timestamp"  : "0x00",
    "alloc"      : {}
 }
```

 # 创世区块配置文件字段说明

字段	取值范围	说明
`config`	对象类型	区块链的网络配置和硬分叉规则
`chainId`	整数：1-65535	链ID，用于区分不同以太坊网络（1:主网, 3:Ropsten, 4:Rinkeby, 5:Goerli, 1337:常见开发链, 其他:私有链）
`homesteadBlock`	整数：0-∞	从第0个区块启用该硬分叉（0:立即启用, >0:在指定区块高度启用, null:禁用该分叉）
`eip150Block`	整数：0-∞	0:立即启用, 与homesteadBlock类似
`eip155Block`	整数：0-∞	0:立即启用, 通常与eip150Block设置相同
`eip158Block`	整数：0-∞	0:立即启用, 必须≥eip155Block
`conibase`	20字节地址	创世区块的矿工地址（以太坊中称`beneficiary`），此处为零地址，因为创世区块无实际矿工
`difficulty`	十六进制字符串：0x1-0xFFFFFFFFFFFFFFFF	初始挖矿难度。值较低便于私有链/测试网快速生成区块
`extraData`	十六进制字符串：0-64字符(0-32字节)	附加信息，可为任意数据（最长32字节）。此处为空，常用于标识矿工或添加备注
`gasLimit`	十六进制字符串：0x15F90-0xFFFFFFFF	每个区块的Gas上限，限制区块内交易的总计算量。此值约为以太坊主网初始值（500万）的60%
`nonce`	十六进制字符串：0x0-0xFFFFFFFFFFFFFFFF	与mixhash配合用于工作量证明（PoW）的随机数。创世区块中该值通常固定
`mixhash`	32字节哈希值(64字符)	PoW算法中与nonce共同生成区块哈希的哈希值。创世区块固定为零哈希
`parentHash`	32字节哈希值(64字符)	父区块哈希。创世区块无父区块，故为零哈希
`timestamp`	十六进制字符串：0x0-0xFFFFFFFF	创世区块生成时间戳（Unix时间戳）。0表示1970年1月1日，实际运行时会更新
`alloc`	对象或空对象{}	预分配初始账户和余额。此处为空对象，表示无预挖代币



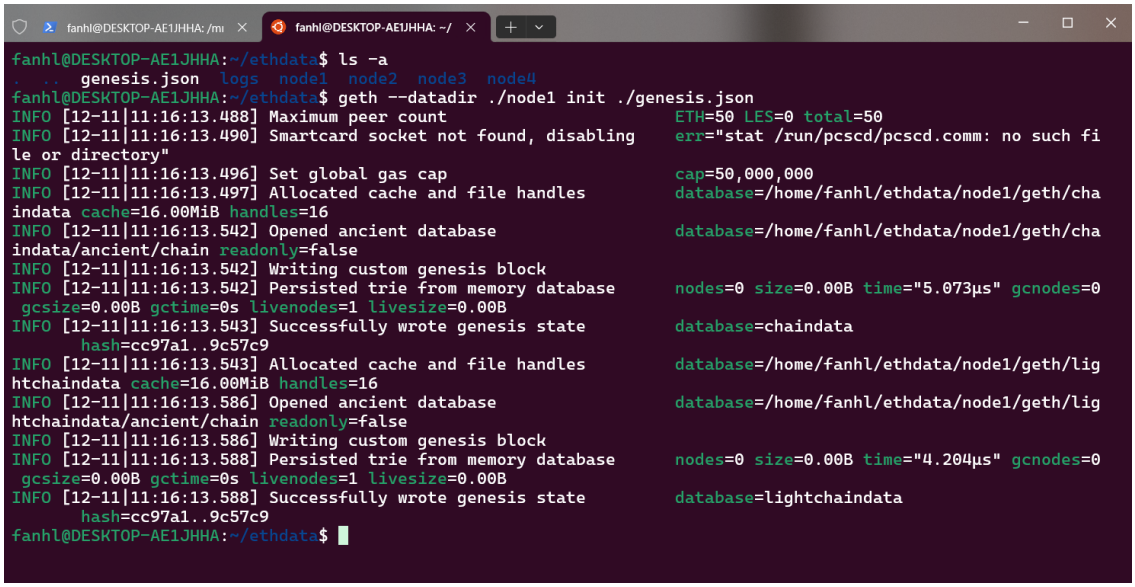
2.2. 启动私链

- **初始化以太坊4个节点的Geth客户端**

```
# 当前目录 /home/fanhl/ethdata

# node1
geth --datadir ./node1 init ./genesis.json

# node2
geth --datadir ./node2 init ./genesis.json

# node3
geth --datadir ./node3 init ./genesis.json

# node4
geth --datadir ./node4 init ./genesis.json
```

 # 以太坊节点初始化命令说明

参数	说明
`geth`	可执行文件，Go Ethereum客户端的主程序
`--datadir ./node`	数据目录参数，指定节点数据的存储位置
`init`	初始化命名，创建新区块链的初始化操作
`./genesis.json`	创世文件路径，定义区块链初始状态的配置文件



- **启动私链**

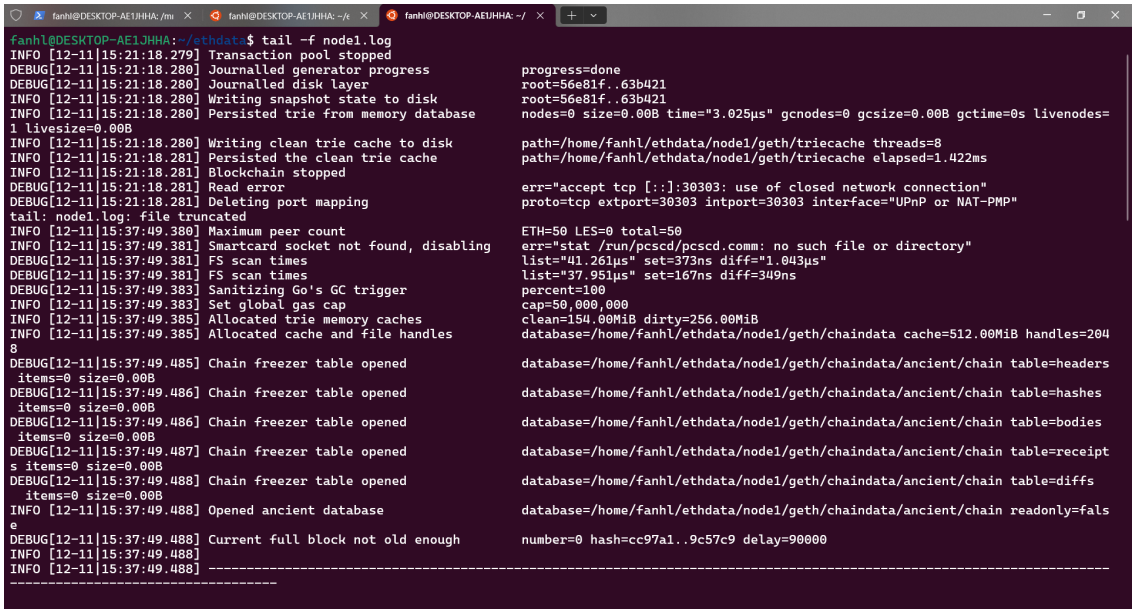
```
# 当前目录 /home/fanhl/ethdata

# node1
geth --datadir ./node1 --networkid 1001 --identity "node1" --port 30303 --http --http.port 8545 --authrpc.port 8551 --nodiscover --verbosity 4 console 2>> node1.log

# node2
geth --datadir ./node2 --networkid 1001 --identity "node2" --port 30304 --http --http.port 8546 --authrpc.port 8552  --nodiscover --verbosity 4 console 2>> node2.log

# node3
geth --datadir ./node3 --networkid 1001 --identity "node3" --port 30305 --http --http.port 8547 --authrpc.port 8553  --nodiscover --verbosity 4 console 2>> node3.log

# node4
geth --datadir ./node4 --networkid 1001 --identity "node4" --port 30306 --http --http.port 8548 --authrpc.port 8554  --nodiscover --verbosity 4 console 2>> node4.log
```

 # 启动私链命令说明

参数	说明
`--datadir ./node`	指定存储节点数据的目录
`--network 1001`	设置私有网络的网络ID为1001，与配置文件中chainId一致，同一网络需相同
`--identity "node1"`	设置节点名称
`--port 30303`	设置节点间通信端口，默认为以太坊P2P端口
`--http`	开启HHTP-RPC接口，通过HTTP请求与节点交互
`--nodiscover`	禁用自动发现节点，使节点不主动发现其他节点，适用于私有网络
`--verbosity 4`	设置日志详细级别为4，提供较详细的日志输出
`console`	打开Geth的 JavaScript 控制台，允许节点交互
`2 > node.log`	将错误日志输出到文件

- **另开终端监听 log**

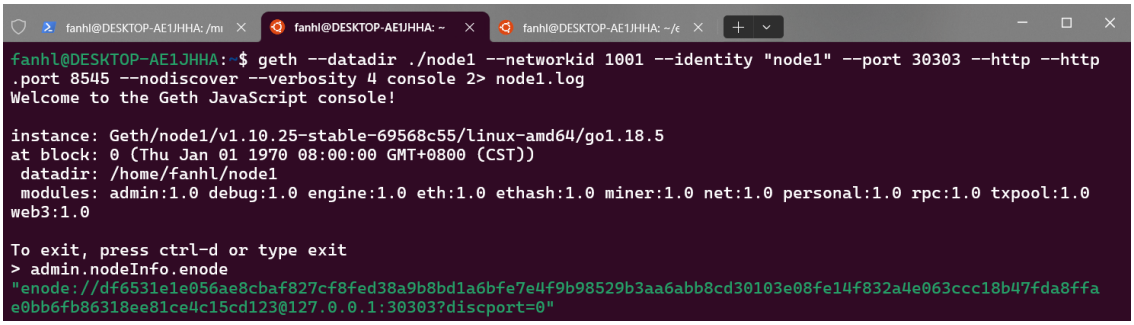
```
# 实时查看 node1.log 文件内容
tail -f node1.log
```



2.3 多节点交互

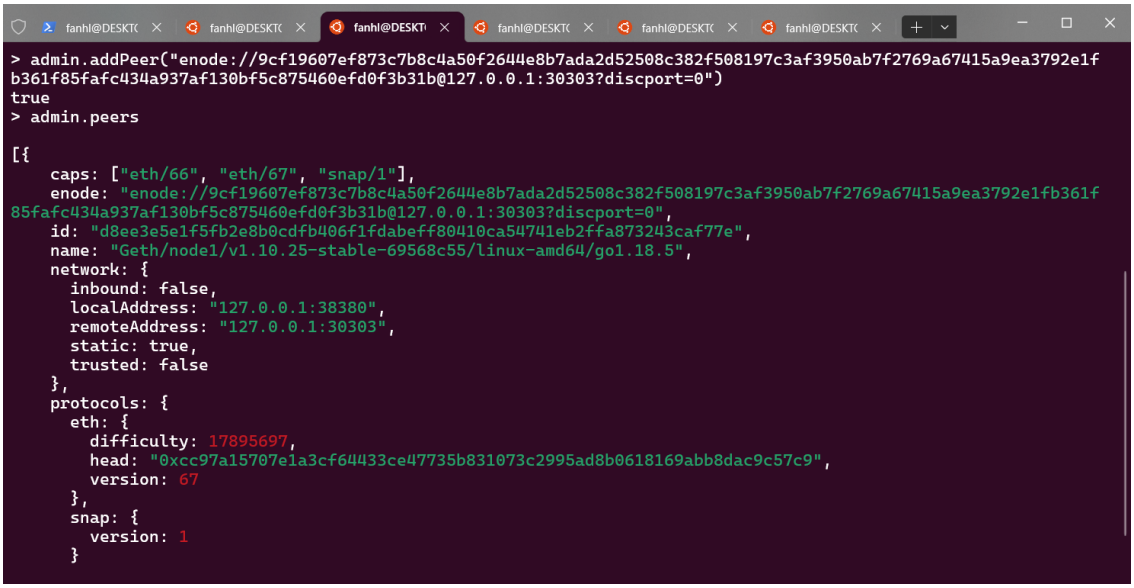
1. 在节点1的控制台中获取enode信息

```
admin.nodeInfo.enode    // 获取node1信息
```



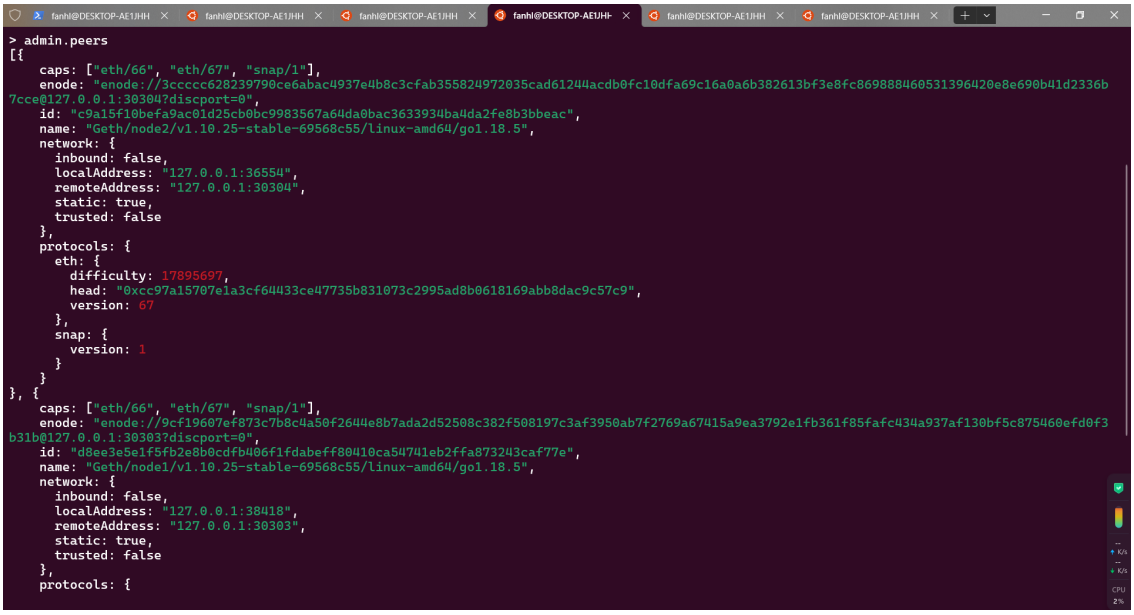
2. 另开新的终端，进入节点2的控制台，添加节点1信息并验证

```
admin.addPeer("从节点1获取的信息")
admin.peers              // 验证节点信息
admin.nodeInfo.enode     // 获取node2信息
```



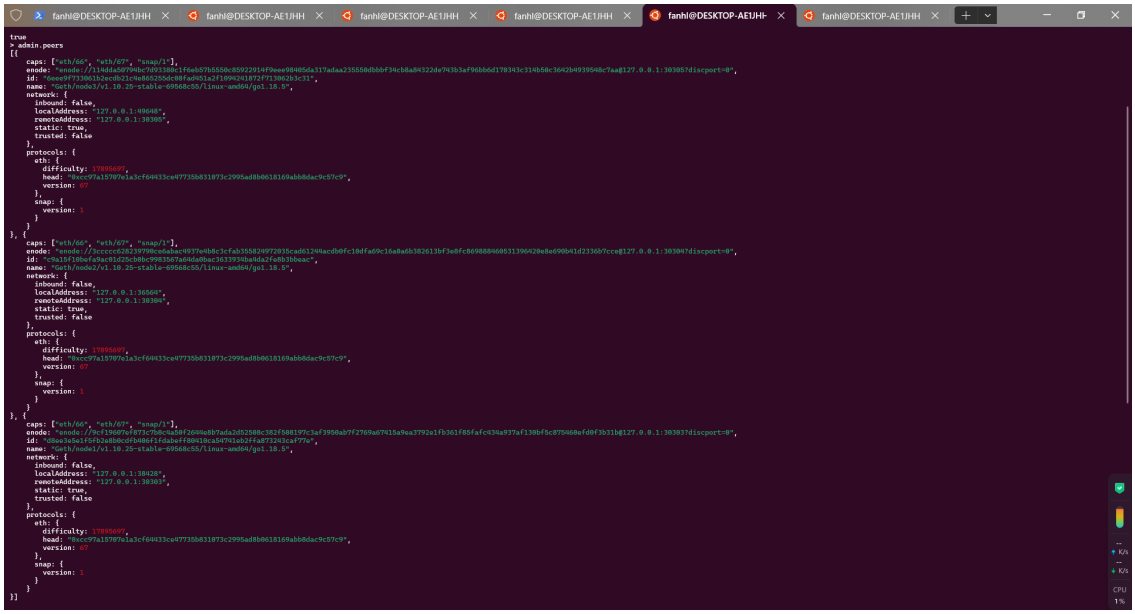
3. 另开新的终端，进入节点3的控制台，添加节点1、2信息并验证

```
admin.addPeer("从节点1获取的信息")
admin.addPeer("从节点2获取的信息")
admin.peers              // 验证节点信息
admin.nodeInfo.enode     // 获取node3信息
```



4. 另开新的终端，进入节点4的控制台，添加节点1、2、3信息并验证

```
admin.addPeer("从节点1获取的信息")
admin.addPeer("从节点2获取的信息")
admin.addPeer("从节点3获取的信息")
admin.peers                 // 验证节点信息
```



2.4 节点信息

- node1

```
{
  enode:
"enode://9cf19607ef873c7b8c4a50f2644e8b7ada2d52508c382f508197c3af3950ab7f276
9a67415a9ea3792e1fb361f85fafc434a937af130bf5c875460efd0f3b31b@127.0.0.1:3030
3?discport=0",
  enr: "enr:-Jy4QPfLn3DorNWd6TonoXPzO0NRXjBdNAOjJhW_ZigyBKWoH1TUspuMpJm70Q-
Ky-
Y9Qw45tcuhXocFLEfX6Qsy3Z6GAZsMRg2Ng2V0aMfGhJ0r3hCAgmlkgnY0gmlwhH8AAAGJc2VjcD
I1NmsxoQOc8ZYH74c8e4xKUPJkTot62i1SUIw4L1CBl8OvOVCrf4RzbmFwwIN0Y3CCdl8",
  id: "d8ee3e5e1f5fb2e8b0cdfb406f1fdabeff80410ca54741eb2ffa873243caf77e",
  ip: "127.0.0.1",
  listenAddr: "[::]:30303",
  name: "Geth/node1/v1.10.25-stable-69568c55/linux-amd64/go1.18.5",
  ports: {
    discovery: 0,
    listener: 30303
  },
  protocols: {
    eth: {
      config: {
        chainId: 1001,
        eip150Block: 0,
        eip150Hash:
"0x0000000000000000000000000000000000000000000000000000000000000000",
        eip155Block: 0,
        eip158Block: 0,
        homesteadBlock: 0
      },
```

```
      difficulty: 17895697,
      genesis:
"0xcc97a15707e1a3cf64433ce47735b831073c2995ad8b0618169abb8dac9c57c9",
      head:
"0xcc97a15707e1a3cf64433ce47735b831073c2995ad8b0618169abb8dac9c57c9",
      network: 1001
    },
    snap: {}
  }
}
```

- node2

```
{
  enode:
"enode://3ccccc628239790ce6abac4937e4b8c3cfab355824972035cad61244acdb0fc10df
a69c16a0a6b382613bf3e8fc869888460531396420e8e690b41d2336b7cce@127.0.0.1:3030
4?discport=0",
  enr: "enr:-
Jy4QFzc77frwgc3d5XqKDMEAH3Gd9nRhpForssf2btmqFWgVXCDxbATyoJ7bCmwUqPTxH3DZinOf
CxiGZpPyKq-
qXuGAZsMSuOQg2V0aMfGhJ0r3hCAgmlkgnY0gmlwhH8AAAGJc2VjcDI1NmsxoQI8zMxigjl5DOar
rEk35LjDz6s1WCSXIDXK1hJErNsPwYRzbmFwwIN0Y3CCdmA",
  id: "c9a15f10befa9ac01d25cb0bc9983567a64da0bac3633934ba4da2fe8b3bbeac",
  ip: "127.0.0.1",
  listenAddr: "[::]:30304",
  name: "Geth/node2/v1.10.25-stable-69568c55/linux-amd64/go1.18.5",
  ports: {
    discovery: 0,
    listener: 30304
  },
  protocols: {
    eth: {
      config: {
        chainId: 1001,
        eip150Block: 0,
        eip150Hash:
"0x0000000000000000000000000000000000000000000000000000000000000000",
        eip155Block: 0,
        eip158Block: 0,
        homesteadBlock: 0
      },
      difficulty: 17895697,
      genesis:
"0xcc97a15707e1a3cf64433ce47735b831073c2995ad8b0618169abb8dac9c57c9",
      head:
"0xcc97a15707e1a3cf64433ce47735b831073c2995ad8b0618169abb8dac9c57c9",
      network: 1001
    },
    snap: {}
  }
}
```

- node3

```
{
```

```
  enode:
"enode://114dda50794bc7d93380c1f6eb57b5550c85922914f9eee98405da317adaa235550
dbbbf34cb8a84322de743b3af96bb6d170343c314b50c3642b4939548c7aa@127.0.0.1:3030
5?discport=0",
  enr: "enr:-Jy4QIfWxeoGr_QICUodrWZnHUhznjWERKzkFXyhS2Y5bDD9CIsMO5LMwCFukAY-
7w1mGYGutldNBLWjJzgA17L1_XqGAZsMSxOkg2V0aMfGhJ0r3hCAgmlkgnY0gmlwhH8AAAGJc2Vj
cDI1NmsxoQIRTdpQeUvH2TOAwfbrV7VVDIWSKRT57umEBdoxetqiNYRzbmFwwIN0Y3CCdmE",
  id: "6eee9f733061b2ecdb21c4e865255dc08fad451a2f1094241872f713062b3c31",
  ip: "127.0.0.1",
  listenAddr: "[::]:30305",
  name: "Geth/node3/v1.10.25-stable-69568c55/linux-amd64/go1.18.5",
  ports: {
    discovery: 0,
    listener: 30305
  },
  protocols: {
    eth: {
      config: {
        chainId: 1001,
        eip150Block: 0,
        eip150Hash:
"0x0000000000000000000000000000000000000000000000000000000000000000",
        eip155Block: 0,
        eip158Block: 0,
        homesteadBlock: 0
      },
      difficulty: 17895697,
      genesis:
"0xcc97a15707e1a3cf64433ce47735b831073c2995ad8b0618169abb8dac9c57c9",
      head:
"0xcc97a15707e1a3cf64433ce47735b831073c2995ad8b0618169abb8dac9c57c9",
      network: 1001
    },
    snap: {}
  }
}
```


- node4


```
{
  enode:
"enode://a360182b893a90f3f769d2116d239c0a354a020c7c6bb9463cd76822a82c060942d
3c92330ef7aaf59e416dc292011f5863a6c511623ec63567ece626e83e392@127.0.0.1:3030
6?discport=0",
  enr: "enr:-
Jy4QHdRgoZqgJM5UKriSCl2kHHc8RH0AWyVhk0AtWH_JkpoA26cR8QomHcIRfN72JMfVFkw_JmEc
SYrEGYQoxx30y2GAZsMSzLPg2V0aMfGhJ0r3hCAgmlkgnY0gmlwhH8AAAGJc2VjcDI1NmsxoQKjY
BgriTqQ8_dp0hFtI5wKNUoCDHxruUY812giqCwGCYRzbmFwwIN0Y3CCdmI",
  id: "5a153cbdee056a0b6a1485339705b71f8d9a179c0efe786b77edc132437f2eba",
  ip: "127.0.0.1",
  listenAddr: "[::]:30306",
  name: "Geth/node4/v1.10.25-stable-69568c55/linux-amd64/go1.18.5",
  ports: {
    discovery: 0,
    listener: 30306
  },
  protocols: {
```

```
    eth: {
      config: {
        chainId: 1001,
        eip150Block: 0,
        eip150Hash:
"0x0000000000000000000000000000000000000000000000000000000000000000",
        eip155Block: 0,
        eip158Block: 0,
        homesteadBlock: 0
      },
      difficulty: 17895697,
      genesis:
"0xcc97a15707e1a3cf64433ce47735b831073c2995ad8b0618169abb8dac9c57c9",
      head:
"0xcc97a15707e1a3cf64433ce47735b831073c2995ad8b0618169abb8dac9c57c9",
      network: 1001
    },
    snap: {}
  }
}
```

3. Remix连接

3.1 创建账户与ETH获取

> 合约部署需要账户中ETH > 0，预先挖矿，获取一些ETH

1. 启动节点1，进入JavaScript控制台

```
geth --datadir ./node1 --networkid 1001 --identity "node1" --port 30303 --
http --http.port 8545 --nodiscover --verbosity 4 console 2> node1.log
```

2. 创建新账户，将提示输入密码，并生成一个新的以太坊地址

```
# 两种方式
personal.newAccount()        // 创建新账户，需要再设置密码
personal.newAccount("lab1") // 创建一个密码为lab1的账户
```

```
> fanhl@DESKTOP-AE1JHHA:~/ethdata$ geth --datadir ./node1 --networkid 1001 --identity "node1" --port 30303 --h
ttp --http.port 8545 --nodiscover --verbosity 4 console 2> node1.log
Welcome to the Geth JavaScript console!

instance: Geth/node1/v1.10.25-stable-69568c55/linux-amd64/go1.18.5
at block: 0 (Thu Jan 01 1970 08:00:00 GMT+0800 (CST))
 datadir: /home/fanhl/ethdata/node1
 modules: admin:1.0 debug:1.0 engine:1.0 eth:1.0 ethash:1.0 miner:1.0 net:1.0 personal:1.0 rpc:1.0 txpool:1.0
web3:1.0

To exit, press ctrl-d or type exit
> personal.newAccount()
Passphrase:
Repeat passphrase:
"0x9ddc7add63e30d46bb8d18548614bcea3357b394"
>
```

3. 挖矿

> 启动挖矿后，虽然显示null但是实际上在后台运行，可以通过查看区块高度看到数字在增长

```
miner.start()    // 启动挖矿
eth.accounts     // 显示在本地创建的所有账户地址
eth.blockNumber // 获得当前区块高度
miner.stop()     //关闭挖矿
```

```
> fanhl@DESKTOP-AE1JHHA:~/ethdata$ geth --datadir ./node1 --networkid 1001 --identity "node1" --port 30303 --h
ttp --http.port 8545 --nodiscover --verbosity 4 console 2> node1.log
Welcome to the Geth JavaScript console!

instance: Geth/node1/v1.10.25-stable-69568c55/linux-amd64/go1.18.5
at block: 0 (Thu Jan 01 1970 08:00:00 GMT+0800 (CST))
 datadir: /home/fanhl/ethdata/node1
 modules: admin:1.0 debug:1.0 engine:1.0 eth:1.0 ethash:1.0 miner:1.0 net:1.0 personal:1.0 rpc:1.0 txpool:1.0
web3:1.0

To exit, press ctrl-d or type exit
> personal.newAccount()
Passphrase:
Repeat passphrase:
"0x9ddc7add63e30d46bb8d18548614bcea3357b394"
> miner.start()
null
> miner.stop()
null
> eth.accounts
["0x9ddc7add63e30d46bb8d18548614bcea3357b394"]
> eth.blockNumber
0
>
```

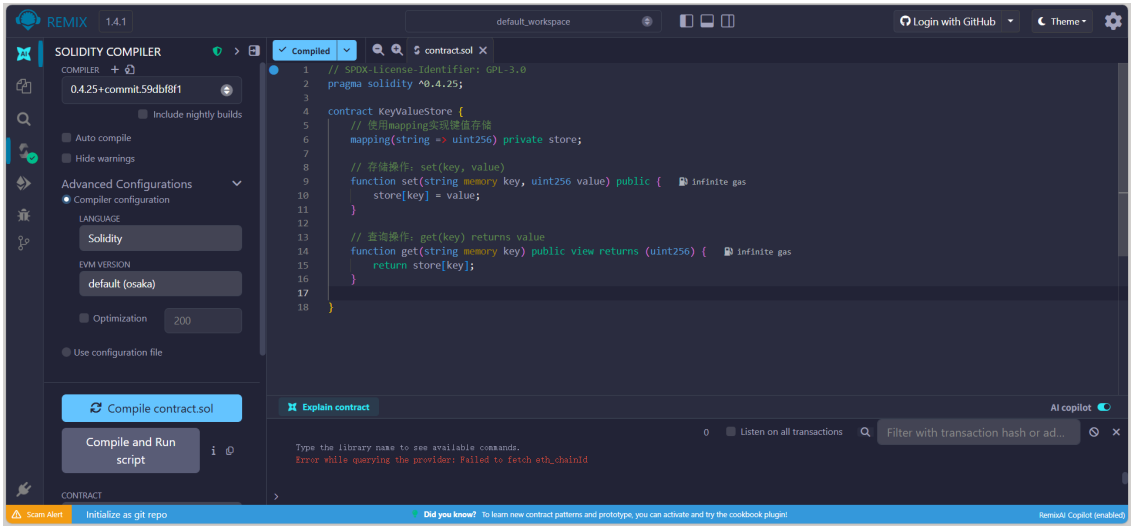
```
> miner.start()
null
> eth.blockNumber
13
> eth.accounts
["0x9ddc7add63e30d46bb8d18548614bcea3357b394", "0xf595c507fdbb3d00ab3deca5693a1053f6f6e3e8"]
>
```

3.2 创建并编译合约

1. 进入 https://remix.ethereum.org/ ，在 Remix 顶部选择默认工作台 `defualt_workspace`
2. 在 `File Explorer` 页面新建 `contract.sol` 文件，用于存储与查询键值对

```solidity
// SPDX-License-Identifier: GPL-3.0
pragma solidity ^0.4.25;

contract KeyValueStore {
    // 使用mapping实现键值存储
    mapping(string => uint256) private store;

    // 存储操作：set(key, value)
    function set(string memory key, uint256 value) public {
        store[key] = value;
    }

    // 查询操作：get(key) returns value
    function get(string memory key) public view returns (uint256) {
        return store[key];
    }
}
```

3. 在 `Solidity Compiler` 页面点击 `Compiled` 编译该文件，出现 `√` 即编译成功



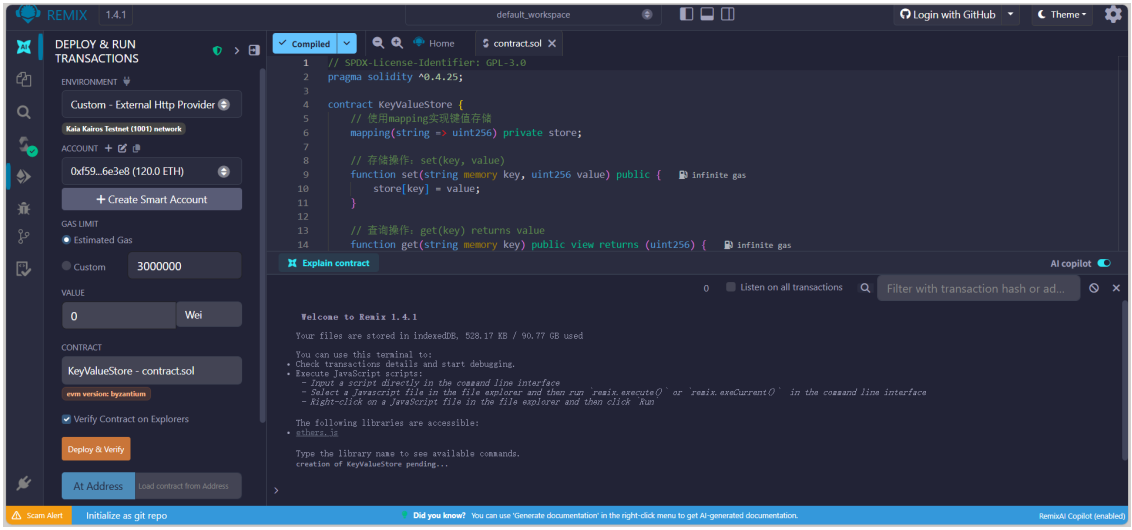
3.3 连接Remix并部署合约

1. 添加http参数后，重新启动节点1，否则无法连接Remix

```
# node1
geth --datadir ./node1 --networkid 1001 --identity "node1" --port 30303 --
http --http.port 8545 --http.corsdomain "https://remix.ethereum.org" --
http.api "web3,eth,debug,personal,net" --authrpc.port 8551 --allow-insecure-
unlock --nodiscover --verbosity 4 console 2>> node1.log
```

2. 在 `Deploy & run transactions` 页面，配置相关信息，点击 `Deploy & Verify`

```
# 可能出现报错的几种情况与解决方法
1. 环境配置下面出现can't detect network提示
    - 可能是选择 Custom - External Http Provider 时需要填写的http与实际的节点1启动
时的http.port参数值不相符
    - 可能说明节点1的http配置有问题需要检查参数并重新启动
    - 也可能是--allow-insecure-unlock未生效，启动节点1后并未解锁账户，在启动节点1后使
用命令personal.unlockAccount(eth.accounts[0], "你的密码", 0)单独解锁账户，结果返回
true则解锁成功
    - 以上操作完成后，需要刷新remix页面
2. ETH为0导致部署失败，需要在节点1中预先挖矿，获取一定ETH，Remix中选择ACCOUNT时可以看见
账户余额
```

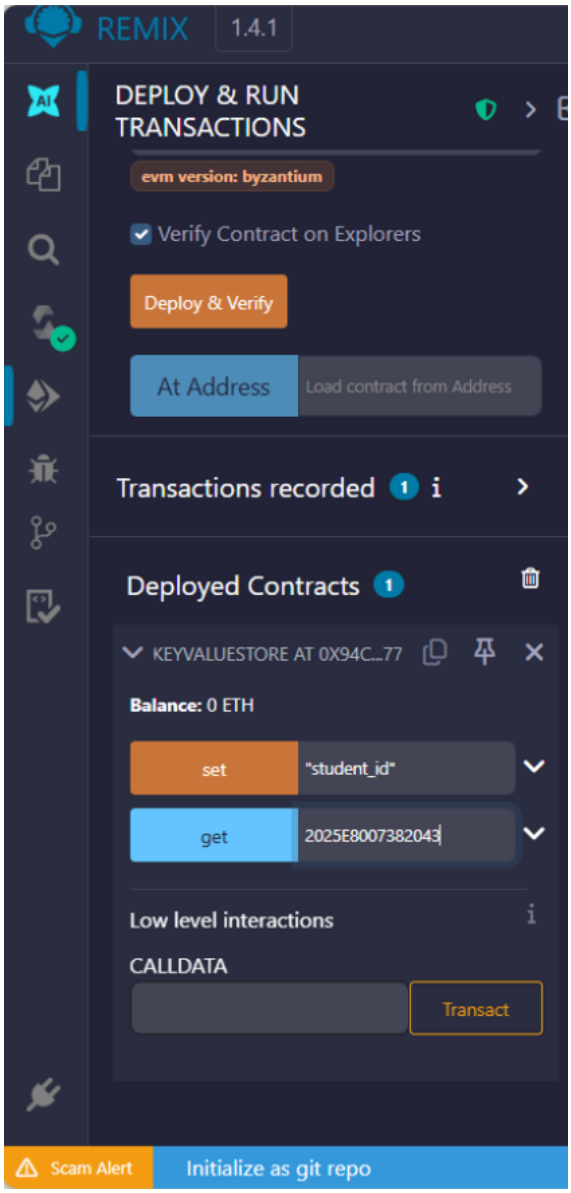


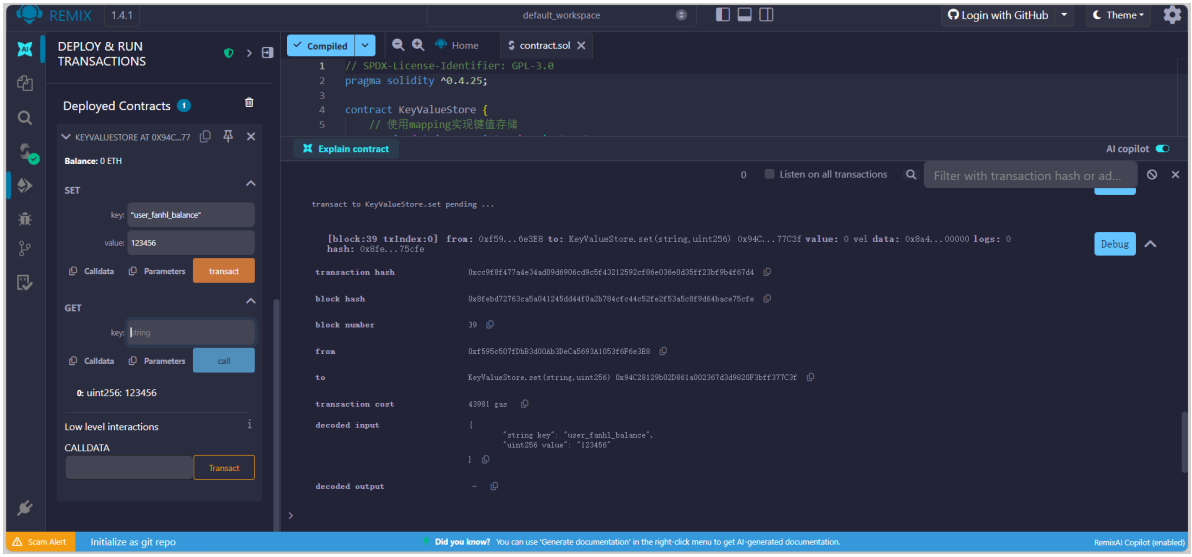
3. 部署成功可以看到 `creation of KeyValueStore pending...` 表示交易正在提交，这时在节点1中输入miner.start()，等待一会儿，当deplyed contracts有内容可展开时，再miner.stop()，此时 `Deployed Contracts` 可以展开

> 合约地址：0x94C28129b02D861a002367d3d9820F3bff377C3f

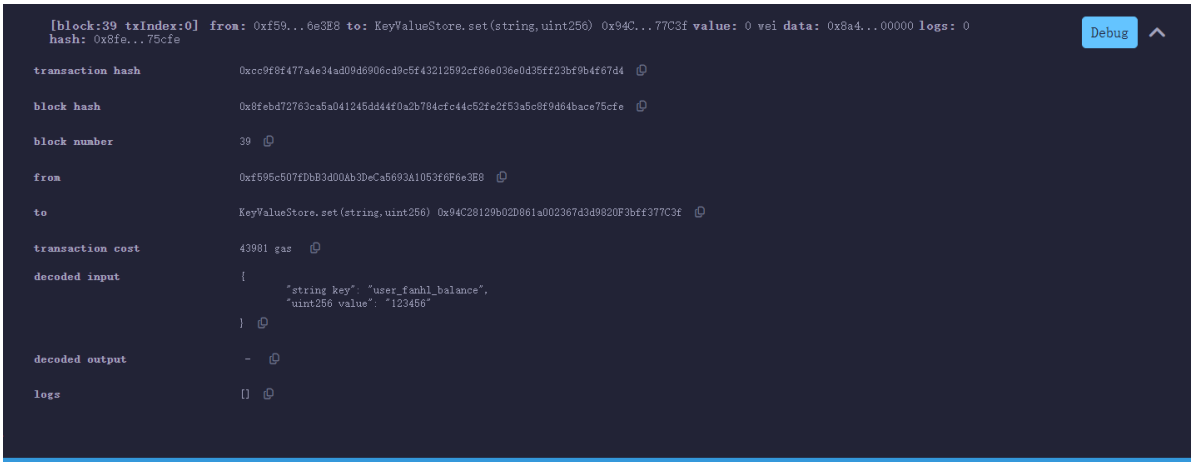
填写set内容，点击 `transact`

> key："user_fanhl_balance"
>
> value："123456"





5. 在节点1中输入miner.start()，短暂挖矿确认交易，等待一会儿，当终端有内容可展开时，再miner.stop()



6. 在Remix的 `Deployed Contracts` 中`get`输入相应的key后，点击call，可以获取对应value