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# **Лабораторна робота 1**

## **з предмету «Вступ в технологію Блокчейн»**

Тема: “Розгортання систем Ethereum та криптовалют”

**Роботу виконали:**

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**Мета роботи:** Отримання навичок налаштування платформ виконання смарт контрактів та криптовалюти.

**Другий тип лабораторної роботи:** Провести налаштування обраної системи та виконати тестові операції в системі **Ethereum**.

В цій лабораторній роботі ми спробуємо налаштувати та перевірити локальну р2р систему Ethereum. Як основу для виконання візьмемо офіційний гайд від розробників geth [Private Networks | go-ethereum](#). А також скористаємось дуже великою кількістю фантазії, щоб налаштувати PoS, бо PoA застарів :D.

## Підготовка та попередні встановлення

Встановимо необхідні утиліти, в першу чергу – власне сам Ethereum.

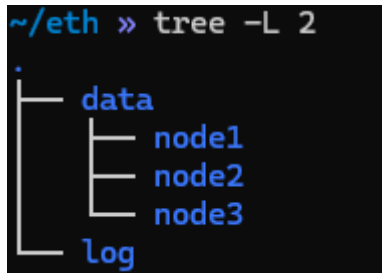
```
~ » sudo add-apt-repository ppa:ethereum/ethereum
[sudo] password for petrob:
Repository: 'deb https://ppa.launchpadcontent.net/ethereum/ethereum/ubuntu/ jammy main'
More info: https://launchpad.net/~ethereum/+archive/ubuntu/ethereum
Adding repository.
Press [ENTER] to continue or Ctrl-c to cancel.
Adding deb entry to /etc/apt/sources.list.d/ethereum-ubuntu-ethereum-jammy.list
Adding disabled deb-src entry to /etc/apt/sources.list.d/ethereum-ubuntu-ethereum-jammy.list
Adding key to /etc/apt/trusted.gpg.d/ethereum-ubuntu-ethereum.gpg with fingerprint E66CB8F57F8218E96B13446B50A8D2EE384B7D4
Get:1 file:/var/cuda-repo-wsl-ubuntu-11-6-local InRelease
Ign:1 file:/var/cuda-repo-wsl-ubuntu-11-6-local InRelease
Get:2 file:/var/cuda-repo-wsl-ubuntu-11-6-local Release [564 B]
Get:2 file:/var/cuda-repo-wsl-ubuntu-11-6-local Release [564 B]
Hit:3 http://archive.ubuntu.com/ubuntu jammy InRelease
Get:4 http://archive.ubuntu.com/ubuntu jammy-updates InRelease [128 kB]
Get:5 http://security.ubuntu.com/ubuntu jammy-security InRelease [129 kB]
Get:6 https://apt.repos.intel.com/oneapi all InRelease [5688 B]
Err:7 https://repositories.intel.com/graphics/ubuntu jammy InRelease
 403 Forbidden [IP: 3.161.119.91 443]
Get:9 http://archive.ubuntu.com/ubuntu jammy-backports InRelease [127 kB]
Err:6 https://apt.repos.intel.com/oneapi all InRelease
The following signatures couldn't be verified because the public key is not available: NO_PUBKEY BAC6F0C353D04109
Get:10 https://ppa.launchpadcontent.net/ethereum/ethereum/ubuntu jammy InRelease [18.3 kB]
Get:11 http://archive.ubuntu.com/ubuntu jammy-updates/main amd64 Packages [2623 kB]
Get:12 http://security.ubuntu.com/ubuntu jammy-security/main amd64 Packages [2375 kB]
Get:13 https://ppa.launchpadcontent.net/ethereum/ethereum/ubuntu jammy/main amd64 Packages [2564 B]
Get:14 https://ppa.launchpadcontent.net/ethereum/ethereum/ubuntu jammy/main Translation-en [772 B]
Get:15 http://archive.ubuntu.com/ubuntu jammy-updates/main Translation-en [423 kB]
Get:16 http://archive.ubuntu.com/ubuntu jammy-updates/restricted amd64 Packages [3638 kB]
Get:17 http://security.ubuntu.com/ubuntu jammy-security/main Translation-en [359 kB]
Get:18 http://security.ubuntu.com/ubuntu jammy-security/restricted amd64 Packages [3513 kB]
Get:19 http://security.ubuntu.com/ubuntu jammy-security/restricted Translation-en [628 kB]
Get:20 http://security.ubuntu.com/ubuntu jammy-security/universe amd64 Packages [974 kB]
Get:21 http://security.ubuntu.com/ubuntu jammy-security/universe Translation-en [210 kB]
Get:22 http://security.ubuntu.com/ubuntu jammy-security/multiverse amd64 Packages [39.6 kB]
Get:23 http://archive.ubuntu.com/ubuntu jammy-updates/restricted Translation-en [648 kB]
Get:24 http://archive.ubuntu.com/ubuntu jammy-updates/universe amd64 Packages [1208 kB]
Get:25 http://archive.ubuntu.com/ubuntu jammy-updates/universe Translation-en [298 kB]
Get:26 http://archive.ubuntu.com/ubuntu jammy-updates/multiverse amd64 Packages [46.5 kB]
Get:27 http://archive.ubuntu.com/ubuntu jammy-backports/main amd64 Packages [68.8 kB]
Get:28 http://archive.ubuntu.com/ubuntu jammy-backports/main Translation-en [11.4 kB]
Get:29 http://archive.ubuntu.com/ubuntu jammy-backports/universe amd64 Packages [30.0 kB]
Get:30 http://archive.ubuntu.com/ubuntu jammy-backports/universe Translation-en [16.5 kB]
Reading package lists... Done

~ » sudo apt install ethereum
Get:1 https://ppa.launchpadcontent.net/ethereum/ethereum/ubuntu jammy/main amd64 abigen amd64 1.15.11+build31083+jammy [8392 kB]
Get:2 https://ppa.launchpadcontent.net/ethereum/ethereum/ubuntu jammy/main amd64 clef amd64 1.15.11+build31083+jammy [13.2 MB]
Get:3 https://ppa.launchpadcontent.net/ethereum/ethereum/ubuntu jammy/main amd64 evm amd64 1.15.11+build31083+jammy [11.1 MB]
Get:4 https://ppa.launchpadcontent.net/ethereum/ethereum/ubuntu jammy/main amd64 geth amd64 1.15.11+build31083+jammy [15.0 MB]
Get:5 https://ppa.launchpadcontent.net/ethereum/ethereum/ubuntu jammy/main amd64 rlpdump amd64 1.15.11+build31083+jammy [880 kB]
Get:6 https://ppa.launchpadcontent.net/ethereum/ethereum/ubuntu jammy/main amd64 ethereum amd64 1.15.11+build31083+jammy [1450 B]
Fetched 48.6 MB in 1s (37.8 MB/s)
Selecting previously unselected package abigen.
(Reading database ... 100534 files and directories currently installed.)
Preparing to unpack .../0-abigen_1.15.11+build31083+jammy_amd64.deb ...
Unpacking abigen (1.15.11+build31083+jammy) ...
Selecting previously unselected package clef.
Preparing to unpack .../1-clef_1.15.11+build31083+jammy_amd64.deb ...
Unpacking clef (1.15.11+build31083+jammy) ...
Selecting previously unselected package evm.
Preparing to unpack .../2-evm_1.15.11+build31083+jammy_amd64.deb ...
Unpacking evm (1.15.11+build31083+jammy) ...
Selecting previously unselected package geth.
Preparing to unpack .../3-geth_1.15.11+build31083+jammy_amd64.deb ...
Unpacking geth (1.15.11+build31083+jammy) ...
Selecting previously unselected package rlpdump.
Preparing to unpack .../4-rlpdump_1.15.11+build31083+jammy_amd64.deb ...
Unpacking rlpdump (1.15.11+build31083+jammy) ...
Selecting previously unselected package ethereum.
Preparing to unpack .../5-ethereum_1.15.11+build31083+jammy_amd64.deb ...
Unpacking ethereum (1.15.11+build31083+jammy) ...
Setting up rlpdump (1.15.11+build31083+jammy) ...
Setting up clef (1.15.11+build31083+jammy) ...
Setting up geth (1.15.11+build31083+jammy) ...
Setting up evm (1.15.11+build31083+jammy) ...
Setting up abigen (1.15.11+build31083+jammy) ...
Setting up ethereum (1.15.11+build31083+jammy) ...
```

Це встановить Geth та Clef, якими ми будемо далі користуватися, а також інші допоміжні утиліти.

## Створення вузлів (нод) та їх налаштування

Створимо наступну папкову структуру, що міститиме в собі три ноди:



За допомогою Geth зареєструємо три ноди, передавши параметрами папки цих нод. Після реєстрації ми отримаємо публічні адреси акаунтів (публічний ключ), а також файл, що містить в собі секретний ключ. Він знаходитиметься в папці keystore відповідної ноди.

```
~/eth » geth --datadir data/node1 account new
INFO [06-04|17:03:27.640] Maximum peer count          ETH=50 total=50
INFO [06-04|17:03:27.641] Smartcard socket not found, disabling err="stat /run/pcscd/pcscd.comm: no such file or directory"
Your new account is locked with a password. Please give a password. Do not forget this password.
Password:
Repeat password:

Your new key was generated

Public address of the key:   0x8376C437e12E0a9BDE2313634450f3b3b601c625
Path of the secret key file: data/node1/keystore/UTC--2025-06-04T14-03-29.958727838Z--8376c437e12e0a9bde2313634450f3b3b601c625

- You can share your public address with anyone. Others need it to interact with you.
- You must NEVER share the secret key with anyone! The key controls access to your funds!
- You must BACKUP your key file! Without the key, it's impossible to access account funds!
- You must REMEMBER your password! Without the password, it's impossible to decrypt the key!

(base)
~/eth » geth --datadir data/node2 account new
INFO [06-04|17:03:52.664] Maximum peer count          ETH=50 total=50
INFO [06-04|17:03:52.666] Smartcard socket not found, disabling err="stat /run/pcscd/pcscd.comm: no such file or directory"
Your new account is locked with a password. Please give a password. Do not forget this password.
Password:
Repeat password:

Your new key was generated

Public address of the key:   0xdFf1782f8cd2f99aCFc2F9a4Dcdba10b57DA7a2c
Path of the secret key file: data/node2/keystore/UTC--2025-06-04T14-03-54.431749475Z--dff1782f8cd2f99acfc2f9a4dcdba10b57da7a2c

- You can share your public address with anyone. Others need it to interact with you.
- You must NEVER share the secret key with anyone! The key controls access to your funds!
- You must BACKUP your key file! Without the key, it's impossible to access account funds!
- You must REMEMBER your password! Without the password, it's impossible to decrypt the key!

(base)
~/eth » geth --datadir data/node3 account new
INFO [06-04|17:04:00.762] Maximum peer count          ETH=50 total=50
INFO [06-04|17:04:00.764] Smartcard socket not found, disabling err="stat /run/pcscd/pcscd.comm: no such file or directory"
Your new account is locked with a password. Please give a password. Do not forget this password.
Password:
Repeat password:

Your new key was generated

Public address of the key:   0xE11D619851fA85AB201a93D0E1Db1E6e2d9d05F6
Path of the secret key file: data/node3/keystore/UTC--2025-06-04T14-04-06.624977039Z--e11d619851fa85ab201a93d0e1db1e6e2d9d05f6

- You can share your public address with anyone. Others need it to interact with you.
- You must NEVER share the secret key with anyone! The key controls access to your funds!
- You must BACKUP your key file! Without the key, it's impossible to access account funds!
```

Маємо три акаунти, що будуть учасниками нашої мережі:

0x8376C437e12E0a9BDE2313634450f3b3b601c625

0xdFf1782f8cd2f99aCFc2F9a4Dcdba10b57DA7a2c

0xE11D619851fA85AB201a93D0E1Db1E6e2d9d05F6

```
~/eth » tree -L 4
.
├── data
│   ├── node1
│   │   └── keystore
│   │       └── UTC--2025-06-04T14-03-29.958727838Z--8376c437e12e0a9bde2313634450f3b3b601c625
│   ├── node2
│   │   └── keystore
│   │       └── UTC--2025-06-04T14-03-54.431749475Z--dff1782f8cd2f99acf2cf9a4dcdba10b57da7a2c
│   └── node3
│       └── keystore
│           └── UTC--2025-06-04T14-04-06.624977039Z--e11d619851fa85ab201a93d0e1db1e6e2d9d05f6
├── genesis.json
└── log
```

## Створення Генезис блоку

Для того, щоб підняти мережу та узгодити однакову точку входу, нам треба створити Генезис блок. Зручно, що він представляє із себе просто json-файл із необхідними відомостями та параметрами.

```
~/eth » touch genesis.json
(base)
~/eth » code genesis.json
```

[illegible]

Також, при створенні Генезис блоку ми розподілили початкові баланси між нашими трьома акаунтами.

## Ініціалізація нод використовуючи Генезис блок

Тепер необхідно провести ініціалізацію вузлів за допомогою нашого Генезис блоку.

```
~/eth » geth init --datadir data/node1 genesis.json
INFO [06-04] 17:11:19.533] Maximum peer count ETH=50 total=50
INFO [06-04] 17:11:19.534] Smartcard socket not found, disabling err="stat /run/pcscd/pcscd.comm: no such file or directory"
INFO [06-04] 17:11:19.538] Set global gas cap cap=50,000,000
INFO [06-04] 17:11:19.538] Initializing the KZG library backend=gokzg
INFO [06-04] 17:11:19.541] Defaulting to pebble as the backing database
INFO [06-04] 17:11:19.541] Allocated cache and file handles database=/home/petrob/eth/data/node1/geth/chaindata cache=16.00MiB handles=16
INFO [06-04] 17:11:20.515] Opened ancient database database=/home/petrob/eth/data/node1/geth/chaindata/ancient/chain readonly=false
ERROR [06-04] 17:11:20.516] Head block is not reachable
INFO [06-04] 17:11:20.516] State schema set to default scheme=path
INFO [06-04] 17:11:21.390] Opened ancient database database=/home/petrob/eth/data/node1/geth/chaindata/ancient/state readonly=false
INFO [06-04] 17:11:21.390] Initialized path database cache=16.00MiB buffer=64.00MiB history=90000
INFO [06-04] 17:11:21.390] Writing custom genesis block
INFO [06-04] 17:11:22.292] Successfully wrote genesis state database=chaindata hash=b95bfc..3a8621
(base)

~/eth » geth init --datadir data/node2 genesis.json
INFO [06-04] 17:11:27.074] Maximum peer count ETH=50 total=50
INFO [06-04] 17:11:27.076] Smartcard socket not found, disabling err="stat /run/pcscd/pcscd.comm: no such file or directory"
INFO [06-04] 17:11:27.080] Set global gas cap cap=50,000,000
INFO [06-04] 17:11:27.080] Initializing the KZG library backend=gokzg
INFO [06-04] 17:11:27.080] Defaulting to pebble as the backing database
INFO [06-04] 17:11:27.081] Allocated cache and file handles database=/home/petrob/eth/data/node2/geth/chaindata cache=16.00MiB handles=16
INFO [06-04] 17:11:28.015] Opened ancient database database=/home/petrob/eth/data/node2/geth/chaindata/ancient/chain readonly=false
INFO [06-04] 17:11:28.015] State schema set to default scheme=path
ERROR [06-04] 17:11:28.015] Head block is not reachable
INFO [06-04] 17:11:28.723] Opened ancient database database=/home/petrob/eth/data/node2/geth/chaindata/ancient/state readonly=false
INFO [06-04] 17:11:28.724] Initialized path database cache=16.00MiB buffer=64.00MiB history=90000
INFO [06-04] 17:11:28.724] Writing custom genesis block
INFO [06-04] 17:11:29.499] Successfully wrote genesis state database=chaindata hash=b95bfc..3a8621
(base)

~/eth » geth init --datadir data/node3 genesis.json
INFO [06-04] 17:11:33.189] Maximum peer count ETH=50 total=50
INFO [06-04] 17:11:33.190] Smartcard socket not found, disabling err="stat /run/pcscd/pcscd.comm: no such file or directory"
INFO [06-04] 17:11:33.192] Set global gas cap cap=50,000,000
INFO [06-04] 17:11:33.192] Initializing the KZG library backend=gokzg
INFO [06-04] 17:11:33.195] Defaulting to pebble as the backing database
INFO [06-04] 17:11:33.195] Allocated cache and file handles database=/home/petrob/eth/data/node3/geth/chaindata cache=16.00MiB handles=16
INFO [06-04] 17:11:34.133] Opened ancient database database=/home/petrob/eth/data/node3/geth/chaindata/ancient/chain readonly=false
INFO [06-04] 17:11:34.134] State schema set to default scheme=path
ERROR [06-04] 17:11:34.134] Head block is not reachable
INFO [06-04] 17:11:34.883] Opened ancient database database=/home/petrob/eth/data/node3/geth/chaindata/ancient/state readonly=false
INFO [06-04] 17:11:34.883] Initialized path database cache=16.00MiB buffer=64.00MiB history=90000
INFO [06-04] 17:11:34.883] Writing custom genesis block
INFO [06-04] 17:11:35.749] Successfully wrote genesis state database=chaindata hash=b95bfc..3a8621
```

Це створить у файловій системі всі необхідні відомості про блокчейн для кожної ноди.

```
~/eth » tree -L 4
.
├── data
│   ├── node1
│   │   ├── geth
│   │   │   ├── LOCK
│   │   │   ├── chaindata
│   │   │   └── nodekey
│   │   └── keystore
│   │       └── UTC--2025-06-04T14-03-29.958727838Z--8376c437e12e0a9bde2313634450f3b3b601c625
│   ├── node2
│   │   ├── geth
│   │   │   ├── LOCK
│   │   │   ├── chaindata
│   │   │   └── nodekey
│   │   └── keystore
│   │       └── UTC--2025-06-04T14-03-54.431749475Z--dff1782f8cd2f99acf2f9a4dcdba10b57da7a2c
│   └── node3
│       ├── geth
│       │   ├── LOCK
│       │   ├── chaindata
│       │   └── nodekey
│       └── keystore
│           └── UTC--2025-06-04T14-04-06.624977039Z--e11d619851fa85ab201a93d0e1db1e6e2d9d05f6
├── genesis.json
└── log
```

## Налаштування менеджера ключів

Для зручності демонстрації скопіюємо всі ключі в одну папку та завантажимо їх в менеджер ключів Clef. Він має бути запущеним на фоні, для підтвердження транзакцій.

```
(base)
~/eth » mkdir clef-merged-keystore
(base)
~/eth » cp **/keystore/* clef-merged-keystore
^C
(base)
~/eth » cp **/keystore/* clef-merged-keystore
(base)
~/eth » ls clef-merged-keystore
UTC--2025-06-04T14-03-29.958727838Z--8376c437e12e0a9bde2313634450f3b3b601c625  UTC--2025-06-04T14-04-06.624977039Z--e11d619851fa85ab201a93d0e1db1e6e2d9d05f6
UTC--2025-06-04T14-03-54.431749475Z--dff1782f8cd2f99acfc2f9a4dcdba10b57da7a2c
~/eth » clef --chainid 1337420 --keystore clef-merged-keystore

WARNING!

Clef is an account management tool. It may, like any software, contain bugs.

Please take care to
- backup your keystore files,
- verify that the keystore(s) can be opened with your password.

Clef is distributed in the hope that it will be useful, but WITHOUT ANY WARRANTY;
without even the implied warranty of MERCHANTABILITY or FITNESS FOR A PARTICULAR
PURPOSE. See the GNU General Public License for more details.

Enter 'ok' to proceed:
> ok

INFO [06-04|21:51:12.246] Using CLI as UI-channel
INFO [06-04|21:51:12.378] Loaded 4byte database                      embeds=268,621 locals=0 local=-./4byte-custom.json
## Master Password

Please enter the password to decrypt the master seed
>
-----
INFO [06-04|21:51:17.194] Starting signer                      chainid=1,337,420 keystore=clef-merged-keystore light-kdf=false advanced=false
INFO [06-04|21:51:17.195] Smartcard socket file missing, disabling  err="stat /run/pcscd/pcscd.comm: no such file or directory"
INFO [06-04|21:51:17.195] Audit logs configured                      file=audit.log
INFO [06-04|21:51:17.196] IPC endpoint opened                       url=/home/petrob/.clef/clef.ipc

----- Signer info -----
* intapi_version : 7.0.1
* extapi_version : 6.1.0
* extapi_http : n/a
* extapi_ipc : /home/petrob/.clef/clef.ipc

----- Available accounts -----
0. 0x8376c437e12e0a98DE2313634450f3b3b601c625 at keystore:///home/petrob/eth/clef-merged-keystore/UTC--2025-06-04T14-03-29.958727838Z--8376c437e12e0a9bde2313634450f3b3b601c625
1. 0xdff1782f8cd2f99acfc2f9a4dcdba10b57da7a2c at keystore:///home/petrob/eth/clef-merged-keystore/UTC--2025-06-04T14-03-54.431749475Z--dff1782f8cd2f99acfc2f9a4dcdba10b57da7a2c
2. 0xE11D619851FA85AB201A93D0E1DB1E6E2D9D05F6 at keystore:///home/petrob/eth/clef-merged-keystore/UTC--2025-06-04T14-04-06.624977039Z--e11d619851fa85ab201a93d0e1db1e6e2d9d05f6
```

Надалі ми будемо використовувати Clef як підписувача транзакцій для всіх наших акаунтів, передаючи параметр `--signer /home/petrob/.clef/clef.ipc`



## Створення вузла запуску (bootloader node, bootnode)

Створюємо бут-ноду на базі node1 (рекомендовано для запуску мережі, альтернативно можна використати розробницьку команду bootnode).

```
eth0: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500
    inet 172.18.244.175 netmask 255.255.240.0 broadcast 172.18.255.255
    inet6 fe80::215:5dff:fee3:5757 prefixlen 64 scopeid 0x20<link>
    ether 00:15:5d:e3:57:57 txqueuelen 1000 (Ethernet)
    RX packets 745451 bytes 810891320 (810.8 MB)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 368573 bytes 53225184 (53.2 MB)
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0
```

- networkid – ідентифікатор мережі блокчейн (1 – для головної мережі Ethereum);
- nat – ідентифікатор локальної мережі, на базі якої буде піднято мережеву комунікацію;
- port/authrpc.port – порти підключення;
- signer – відомості про підписувача (в цьому випадку – наш менеджер ключів).

```
>./eth > geth --datadir data/node1 --networkid 1337420 --nat extip:172.18.244.175 --port 30386 --authrpc.port 8551 --mine --miner.etherbase 0x8376C437e12E0a980E22113634050f3b3b601c625 --signer /home/petrob/.clef/clef.ipc
INFO [06-04]21:14:19.921] Maximum peer count: ETH=50 total=50
INFO [06-04]21:14:19.922] Smartcard socket not found, disabling eno=stat /run/pcscd/pcscd.com: no such file or directory"
INFO [06-04]21:14:19.923] Using external signer url=/home/petrob/.clef/clef.ipc
WARN [06-04]21:14:19.926] Option --miner.etherbase is deprecated as the etherbase is set by the consensus client post-merge
WARN [06-04]21:14:19.926] The flag --mine is deprecated and will be removed
INFO [06-04]21:14:19.927] Set global gas cap: cap=50,000,000
INFO [06-04]21:14:19.927] Initializing the KZG library buildmodeoptkg
INFO [06-04]21:14:19.928] Allocated trie memory caches clean=154.00MiB dirty=256.00MiB
INFO [06-04]21:14:19.928] Using pebble as the backing database database=/home/petrob/eth/data/node1/geth/chaindata cache=512.00MiB txindex=524.288
INFO [06-04]21:14:19.928] Allocated cache and file handles database=/home/petrob/eth/data/node1/geth/chaindata/ancient/chain readonly=false
INFO [06-04]21:14:20.480] Opened ancient database scheme=path
INFO [06-04]21:14:20.480] State scheme set to already existing network=1,337,420 dbversion=9
INFO [06-04]21:14:20.689] Initialising Ethereum protocol database=/home/petrob/eth/data/node1/geth/chaindata/ancient/state readonly=false
INFO [06-04]21:14:20.689] Opened ancient database cache=154.00MiB buffer=256.00MiB history=90000
INFO [06-04]21:14:20.689] Initialized path database
INFO [06-04]21:14:20.689]
-----
INFO [06-04]21:14:20.689] Chain ID: 1337420 (unknown)
INFO [06-04]21:14:20.689] Consensus: Beacon (proof-of-stake), merged from Ethash (proof-of-work)
INFO [06-04]21:14:20.689]
INFO [06-04]21:14:20.689] Pre-Merge hard forks (block based):
INFO [06-04]21:14:20.689] - Homestead: #0 (https://github.com/ethereum/execution-specs/blob/master/network-upgrades/mainnet-upgrades/homestead.md)
INFO [06-04]21:14:20.689] - Tangerine Whistle (EIP 150): #0 (https://github.com/ethereum/execution-specs/blob/master/network-upgrades/mainnet-upgrades/tangerine-whistle.md)
INFO [06-04]21:14:20.689] - Spurious Dragon/1 (EIP 155): #0 (https://github.com/ethereum/execution-specs/blob/master/network-upgrades/mainnet-upgrades/spurious-dragon.md)
INFO [06-04]21:14:20.689] - Spurious Dragon/2 (EIP 158): #0 (https://github.com/ethereum/execution-specs/blob/master/network-upgrades/mainnet-upgrades/spurious-dragon.md)
INFO [06-04]21:14:20.689] - Byzantium: #0 (https://github.com/ethereum/execution-specs/blob/master/network-upgrades/mainnet-upgrades/byzantium.md)
INFO [06-04]21:14:20.689] - Constantinople: #0 (https://github.com/ethereum/execution-specs/blob/master/network-upgrades/mainnet-upgrades/constantinople.md)
INFO [06-04]21:14:20.689] - Petersburg: #0 (https://github.com/ethereum/execution-specs/blob/master/network-upgrades/mainnet-upgrades/petersburg.md)
INFO [06-04]21:14:20.689] - Istanbul: #0 (https://github.com/ethereum/execution-specs/blob/master/network-upgrades/mainnet-upgrades/istanbul.md)
INFO [06-04]21:14:20.689] - Berlin: #0 (https://github.com/ethereum/execution-specs/blob/master/network-upgrades/mainnet-upgrades/berlin.md)
INFO [06-04]21:14:20.689] - London: #0 (https://github.com/ethereum/execution-specs/blob/master/network-upgrades/mainnet-upgrades/london.md)
INFO [06-04]21:14:20.689] - Arrow Glacier: #0 (https://github.com/ethereum/execution-specs/blob/master/network-upgrades/mainnet-upgrades/arrow-glacier.md)
INFO [06-04]21:14:20.689] - Gray Glacier: #0 (https://github.com/ethereum/execution-specs/blob/master/network-upgrades/mainnet-upgrades/gray-glacier.md)
INFO [06-04]21:14:20.689]
INFO [06-04]21:14:20.689] Merge configured:
INFO [06-04]21:14:20.689] - Hard-fork specification: https://github.com/ethereum/execution-specs/blob/master/network-upgrades/mainnet-upgrades/paris.md
INFO [06-04]21:14:20.689] - Network known to be merged:
INFO [06-04]21:14:20.689] - Total terminal difficulty: 0
INFO [06-04]21:14:20.689]
INFO [06-04]21:14:20.689] Post-Merge hard forks (timestamp based):
INFO [06-04]21:14:20.689]
INFO [06-04]21:14:20.689]
INFO [06-04]21:14:20.690] Loaded most recent local block number=0 hash=eedd07..c62040 age=56y2mo3w
INFO [06-04]21:14:20.690] Initialized transaction indexer range="Last 2350000 blocks"
WARN [06-04]21:14:20.690] Invalid log index database version; resetting log index
INFO [06-04]21:14:20.691] Enabled snap sync hash=0 hash-needed07..c62040
INFO [06-04]21:14:20.694] Gasprice oracle is ignoring threshold set threshold=2
WARN [06-04]21:14:20.739] Engine API enabled protocol=eth
INFO [06-04]21:14:20.739] Starting peer-to-peer node instance=geth/v1.15.11-stable-36b2371c/Linux-amd64/go1.24.2
INFO [06-04]21:14:21.054] New local node record sec=1,749,857,131,174 id=id469908b315a6d8 ip=172.18.244.175 udp=30386 tcp=30386
INFO [06-04]21:14:21.100] IPC endpoint opened url=/home/petrob/eth/data/node1/geth.ipc
INFO [06-04]21:14:21.100] Loaded JWT secret file path=/home/petrob/eth/data/node1/geth/jwtsecret sec=32=8x48bd669a
INFO [06-04]21:14:21.102] Started P2P networking self=enode://7a7d3ee31a25127d3f27a9208801fc37d94179212f246b8f39f41080138b13966a3b2875f5b92a56bea7f3f9ded77ae01ef6488667fbb1775859ea7ef1985db7b0
172.18.244.175:30386
INFO [06-04]21:14:21.183] Websocket enabled url=ws://127.0.0.1:8551
INFO [06-04]21:14:21.183] HTTP server started endpoint=127.0.0.1:8551 auth=true prefix=core=localhost what=localhost
WARN [06-04]21:14:21.183] Failed to open wallet url=extapi:///home/petrob/.clef/clef.. err="operation not supported on external signers"
INFO [06-04]21:14:21.184] Started log indexer
INFO [06-04]21:14:31.118] Looking for peers peercount=0 tria=11 static=0
INFO [06-04]21:14:42.620] Looking for peers peercount=0 tria=99 static=0
INFO [06-04]21:14:52.625] Looking for peers peercount=1 tria=55 static=0
```

Отримуємо запис (інформацію) бут-ноди, щоб інші користувачі могли підключитися до мережі

```
>./eth > geth attach --exec admin.nodeInfo enr data/node1/geth.ipc
"enr:-K04QDMaetsvvYJ0MOWcyZT2kUsXMoArmeGZwqS2z3hiq2KkYpgzLMjlf5xvyuuQkrSXwgoK-
zg5NmjyYIG75TC2GjaGAZc77dKmg2V0aMfGhDdB7-CAgmlkgnY0gmlwhKwS9K-
Jc2VjcDI1NmsxoQN6fT7jGiUSft8nqSCIAfw32UF5IS8ka48w9BCAE4sTloRzbmFwwIN0Y3CCdmKDDWR
wgnZi"
```

# Виконуємо підключення інших нод

Для цього запускаємо їх із відповідними параметрами, а також із параметром --bootnode, в який передаємо відомості про бут-ноду.

```
~/eth > geth --datadir data/node2 --networkid 1337428 --bootnodes "enr:-H0uQ0MatsvVvJ3W0Wcy2T2duYXMoArmcG2wq5Zz3hiq2kYpgzJfLFSvxyuuQkrXmg0t-zg5NwJy1G75TCjCjcaGzC77dmq2V8aWfGhDd87-CAgllgnY8galmh4u59K-3c2VjzD11WmaxQn67T7jGUSF7BqgSC1Afz32Uf51S8ka4w98CAE4s1LoR2bmFwIN9Y3CcdmQdWagmZi" --port 30307 --authrpc.port 8552 --mine --miner.etherbase 0xdF1702f8cd2f99aCfc2F9a4Dcd8a18b570A7a2c --signer /home/petrob/.clef/clef.ipc

INFO [06-04|21:29:13.848] Maximum peer count                      ETH=50 total=50
INFO [06-04|21:29:13.851] Smartcard socket not found, disabling   err=stat /run/pcscd/pcscd.comm: no such file or directory"
INFO [06-04|21:29:13.852] Using external signer                   url=/home/petrob/.clef/clef.ipc
WARN [06-04|21:29:13.853] Option --miner.etherbase is deprecated as the etherbase is set by the consensus client post-merge
WARN [06-04|21:29:13.853] The flag --mine is deprecated and will be removed
INFO [06-04|21:29:13.854] Set global gas cap                       cap=50,000,000
INFO [06-04|21:29:13.854] Initializing the KZG library             build=gozkzg
INFO [06-04|21:29:13.845] Allocated trie memory caches            clean=154.00MiB dirty=256.00MiB
INFO [06-04|21:29:13.855] Using pebble as the backing database
INFO [06-04|21:29:13.865] Allocated cache and file handles        database=/home/petrob/eth/data/node2/geth/chaindata cache=512.00MiB handles=524,288
INFO [06-04|21:29:14.427] Opened ancient database                  database=/home/petrob/eth/data/node2/geth/chaindata/ancient/chain readonly=false
INFO [06-04|21:29:14.427] State scheme set to already existing    scheme=path
INFO [06-04|21:29:14.427] Initialising Ethereum protocol          network=1,337,428 dbversion=9
INFO [06-04|21:29:14.635] Opened ancient database                 database=/home/petrob/eth/data/node2/geth/chaindata/ancient/state readonly=false
INFO [06-04|21:29:14.635] Initialized path database                cache=154.00MiB buffer=256.00MiB history=90000

-----
INFO [06-04|21:29:14.635] Chain ID: 1337428 (unknown)
INFO [06-04|21:29:14.635] Consensus: Beacon (proof-of-stake), merged from Ethash (proof-of-work)
INFO [06-04|21:29:14.635]
INFO [06-04|21:29:14.635] Pre-Merge hard forks (block based):
INFO [06-04|21:29:14.635]   - Homestead: #0 (https://github.com/ethereum/execution-specs/blob/master/network-upgrades/mainnet-upgrades/homestead.md)
INFO [06-04|21:29:14.635]   - Tangerine Whistle (EIP 150): #0 (https://github.com/ethereum/execution-specs/blob/master/network-upgrades/mainnet-upgrades/tangerine-whistle.md)
INFO [06-04|21:29:14.635]   - Spurious Dragon/1 (EIP 155): #0 (https://github.com/ethereum/execution-specs/blob/master/network-upgrades/mainnet-upgrades/spurious-dragon.md)
INFO [06-04|21:29:14.635]   - Spurious Dragon/2 (EIP 158): #0 (https://github.com/ethereum/execution-specs/blob/master/network-upgrades/mainnet-upgrades/spurious-dragon.md)
INFO [06-04|21:29:14.635]   - Byzantium: #0 (https://github.com/ethereum/execution-specs/blob/master/network-upgrades/mainnet-upgrades/byzantium.md)
INFO [06-04|21:29:14.635]   - Constantinople: #0 (https://github.com/ethereum/execution-specs/blob/master/network-upgrades/mainnet-upgrades/constantinople.md)
INFO [06-04|21:29:14.635]   - Petersburg: #0 (https://github.com/ethereum/execution-specs/blob/master/network-upgrades/mainnet-upgrades/petersburg.md)
INFO [06-04|21:29:14.635]   - Istanbul: #0 (https://github.com/ethereum/execution-specs/blob/master/network-upgrades/mainnet-upgrades/istanbul.md)
INFO [06-04|21:29:14.635]   - Berlin: #0 (https://github.com/ethereum/execution-specs/blob/master/network-upgrades/mainnet-upgrades/berlin.md)
INFO [06-04|21:29:14.635]   - Arrow Glacier: #0 (https://github.com/ethereum/execution-specs/blob/master/network-upgrades/mainnet-upgrades/arrow-glacier.md)
INFO [06-04|21:29:14.635]   - Gray Glacier: #0 (https://github.com/ethereum/execution-specs/blob/master/network-upgrades/mainnet-upgrades/gray-glacier.md)
INFO [06-04|21:29:14.635]
INFO [06-04|21:29:14.635] Merge configured:
INFO [06-04|21:29:14.635]   - Hard-fork specification: https://github.com/ethereum/execution-specs/blob/master/network-upgrades/mainnet-upgrades/paris.md
INFO [06-04|21:29:14.635]   - Network known to be merged
INFO [06-04|21:29:14.635]   - Total terminal difficulty: 0
INFO [06-04|21:29:14.635]
INFO [06-04|21:29:14.635] Post-Merge hard forks (timestamp based):
INFO [06-04|21:29:14.635]
INFO [06-04|21:29:14.636] Loaded most recent local block          number=0 hash=eedd077..c62040 age=56y2m0w3
INFO [06-04|21:29:14.636] Initialized transaction indexer          range="Last 2350000 blocks"
WARN [06-04|21:29:14.636] Invalid log index database version; resetting log index
INFO [06-04|21:29:14.643] Enabled snap sync                       hex=0 hash=eedd077..c62040

INFO [06-04|21:29:14.643] Gasprice oracle is ignoring threshold set threshold=2
WARN [06-04|21:29:14.690] Engine API enabled                      protocol=eth
INFO [06-04|21:29:14.690] Starting peer-to-peer node              instance=Geth/v1.15.11-stable-36b2371c/Linux-amd64/go1.24.2
INFO [06-04|21:29:15.194] New local node record                   seq=1,749,057,170,057 id=aeae424aad849b11f ip=127.0.0.1 udp=30307 tcp=30307
INFO [06-04|21:29:15.131] Started P2P networking                  self=ende://af454782a93a8c38f33044f152ca8f919f048ead01d6e4015f54385a37f588968342fa54932706ae3dc35b542e129f260446c8ed6b6ccdb94ac8961ede9e127.0.0.1:30307
INFO [06-04|21:29:15.131] IPC endpoint opened                     url=/home/petrob/eth/data/node2/geth.ipc
INFO [06-04|21:29:15.131] Loaded JMT secret file                  path=/home/petrob/eth/data/node2/geth/jwtsecret crc32=0xf93ebf3
INFO [06-04|21:29:15.132] Websocket enabled                       url=ws://127.0.0.1:8552
INFO [06-04|21:29:15.132] HTTP server started                     http=ws://127.0.0.1:8553 url=true prefix= cors=localhost whost=localhost
WARN [06-04|21:29:15.132] Failed to open wallet                   url=extapi:///home/petrob/.clef/cle.. err=operation not supported on external signers"
INFO [06-04|21:29:15.132] Started log indexer
INFO [06-04|21:29:23.973] New local node record                   seq=1,749,057,170,058 id=aeae424aad849b11f ip=91.123.154.235 udp=19455 tcp=30307
INFO [06-04|21:29:28.381] Looking for peers                       peercount=1 trise=0 status=0
INFO [06-04|21:29:28.763] Looking for peers                       peercount=1 trise=0 status=0

~/eth > geth --datadir data/node3 --networkid 1337428 --bootnodes "enr:-H0uQ0MatsvVvJ3W0Wcy2T2duYXMoArmcG2wq5Zz3hiq2kYpgzJfLFSvxyuuQkrXmg0t-zg5NwJy1G75TCjCjcaGzC77dmq2V8aWfGhDd87-CAgllgnY8galmh4u59K-3c2VjzD11WmaxQn67T7jGUSF7BqgSC1Afz32Uf51S8ka4w98CAE4s1LoR2bmFwIN9Y3CcdmQdWagmZi" --port 30308 --authrpc.port 8553 --mine --miner.etherbase 0xdE11D619681fA854261a93D8C1Bb1f6cd2d9d85f6 --signer /home/petrob/.clef/clef.ipc

INFO [06-04|21:29:28.885] Maximum peer count                      ETH=50 total=50
INFO [06-04|21:29:28.885] Smartcard socket not found, disabling   err=stat /run/pcscd/pcscd.comm: no such file or directory"
INFO [06-04|21:29:28.886] Using external signer                   url=/home/petrob/.clef/clef.ipc
WARN [06-04|21:29:28.888] Option --miner.etherbase is deprecated as the etherbase is set by the consensus client post-merge
WARN [06-04|21:29:28.888] The flag --mine is deprecated and will be removed
INFO [06-04|21:29:28.888] Set global gas cap                       cap=50,000,000
INFO [06-04|21:29:28.890] Initializing the KZG library             build=gozkzg
INFO [06-04|21:29:28.890] Allocated trie memory caches            clean=154.00MiB dirty=256.00MiB
INFO [06-04|21:29:28.890] Using pebble as the backing database
INFO [06-04|21:29:28.890] Allocated cache and file handles        database=/home/petrob/eth/data/node3/geth/chaindata cache=512.00MiB handles=524,288
INFO [06-04|21:29:21.436] Opened ancient database                  database=/home/petrob/eth/data/node3/geth/chaindata/ancient/chain readonly=false
INFO [06-04|21:29:21.437] State scheme set to already existing    scheme=path
INFO [06-04|21:29:21.437] Initialising Ethereum protocol          network=1,337,428 dbversion=9
INFO [06-04|21:29:21.683] Opened ancient database                 database=/home/petrob/eth/data/node3/geth/chaindata/ancient/state readonly=false
INFO [06-04|21:29:21.683] Initialized path database                cache=154.00MiB buffer=256.00MiB history=90000

-----
INFO [06-04|21:29:21.683] Chain ID: 1337428 (unknown)
INFO [06-04|21:29:21.683] Consensus: Beacon (proof-of-stake), merged from Ethash (proof-of-work)
INFO [06-04|21:29:21.683]
INFO [06-04|21:29:21.684] Pre-Merge hard forks (block based):
INFO [06-04|21:29:21.684]   - Homestead: #0 (https://github.com/ethereum/execution-specs/blob/master/network-upgrades/mainnet-upgrades/homestead.md)
INFO [06-04|21:29:21.684]   - Tangerine Whistle (EIP 150): #0 (https://github.com/ethereum/execution-specs/blob/master/network-upgrades/mainnet-upgrades/tangerine-whistle.md)
INFO [06-04|21:29:21.684]   - Spurious Dragon/1 (EIP 155): #0 (https://github.com/ethereum/execution-specs/blob/master/network-upgrades/mainnet-upgrades/spurious-dragon.md)
INFO [06-04|21:29:21.684]   - Spurious Dragon/2 (EIP 158): #0 (https://github.com/ethereum/execution-specs/blob/master/network-upgrades/mainnet-upgrades/spurious-dragon.md)
INFO [06-04|21:29:21.684]   - Byzantium: #0 (https://github.com/ethereum/execution-specs/blob/master/network-upgrades/mainnet-upgrades/byzantium.md)
INFO [06-04|21:29:21.684]   - Constantinople: #0 (https://github.com/ethereum/execution-specs/blob/master/network-upgrades/mainnet-upgrades/constantinople.md)
INFO [06-04|21:29:21.684]   - Petersburg: #0 (https://github.com/ethereum/execution-specs/blob/master/network-upgrades/mainnet-upgrades/petersburg.md)
INFO [06-04|21:29:21.684]   - Istanbul: #0 (https://github.com/ethereum/execution-specs/blob/master/network-upgrades/mainnet-upgrades/istanbul.md)
INFO [06-04|21:29:21.684]   - Berlin: #0 (https://github.com/ethereum/execution-specs/blob/master/network-upgrades/mainnet-upgrades/berlin.md)
INFO [06-04|21:29:21.684]   - London: #0 (https://github.com/ethereum/execution-specs/blob/master/network-upgrades/mainnet-upgrades/london.md)
INFO [06-04|21:29:21.684]   - Arrow Glacier: #0 (https://github.com/ethereum/execution-specs/blob/master/network-upgrades/mainnet-upgrades/arrow-glacier.md)
INFO [06-04|21:29:21.684]   - Gray Glacier: #0 (https://github.com/ethereum/execution-specs/blob/master/network-upgrades/mainnet-upgrades/gray-glacier.md)
INFO [06-04|21:29:21.684]
INFO [06-04|21:29:21.684] Merge configured:
INFO [06-04|21:29:21.684]   - Hard-fork specification: https://github.com/ethereum/execution-specs/blob/master/network-upgrades/mainnet-upgrades/paris.md
INFO [06-04|21:29:21.684]   - Network known to be merged
INFO [06-04|21:29:21.684]   - Total terminal difficulty: 0
INFO [06-04|21:29:21.684]
INFO [06-04|21:29:21.684] Post-Merge hard forks (timestamp based):
INFO [06-04|21:29:21.684]
INFO [06-04|21:29:21.684] Loaded most recent local block          number=0 hash=eedd077..c62040 age=56y2m0w3
INFO [06-04|21:29:21.684] Initialized transaction indexer          range="last 2350000 blocks"
WARN [06-04|21:29:21.684] Invalid log index database version; resetting log index
INFO [06-04|21:29:21.689] Enabled snap sync                       hex=0 hash=eedd077..c62040

INFO [06-04|21:29:21.689] Gasprice oracle is ignoring threshold set threshold=2
WARN [06-04|21:29:21.662] Engine API enabled                      protocol=eth
INFO [06-04|21:29:21.662] Starting peer-to-peer node              instance=Geth/v1.15.11-stable-36b2371c/Linux-amd64/go1.24.2
INFO [06-04|21:29:21.985] New local node record                   seq=1,749,057,189,369 id=6f19fc27ee5518d ip=127.0.0.1 udp=30308 tcp=30308
INFO [06-04|21:29:22.011] Started P2P networking                  self=ende://265240711ba67482c85c8f59805a5dd4fe366884d56bc3718df2e556d993d658cd6dbaf8ba5945f4cf381d3e66c7e800102f6cfaf4ace827fd6323f21da2c8127.0.0.1:30308
INFO [06-04|21:29:22.014] IPC endpoint opened                     url=/home/petrob/eth/data/node3/geth.ipc
INFO [06-04|21:29:22.014] Loaded JMT secret file                  path=/home/petrob/eth/data/node3/geth/jwtsecret crc32=0xe136bddf
INFO [06-04|21:29:22.014] Websocket enabled                       url=ws://127.0.0.1:8553
INFO [06-04|21:29:22.014] HTTP server started                     http=ws://127.0.0.1:8553 url=true prefix= cors=localhost whost=localhost
WARN [06-04|21:29:22.015] Failed to open wallet                   url=extapi:///home/petrob/.clef/cle.. err=operation not supported on external signers"
INFO [06-04|21:29:22.015] Started log indexer
INFO [06-04|21:29:28.158] New local node record                   seq=1,749,057,189,370 id=6f19fc27ee5518d ip=91.123.154.235 udp=19336 tcp=30308
INFO [06-04|21:29:32.093] Looking for peers                       peercount=1 trise=0 status=0
INFO [06-04|21:29:47.048] Looking for peers                       peercount=1 trise=0 status=0
```



## Підключаємо JS консоль для керування

Підключимо Java Script консоль для виконання операцій на вузлі 1. Перевіримо підключених до нього учасників (peers) та його баланс.

```
~/eth > geth attach data/node1/geth.ipc
Welcome to the Geth JavaScript console!

instance: Geth/v1.15.11-stable-36b2371c/linux-amd64/go1.24.2
at block: 0 (Thu Jan 01 1970 03:00:00 GMT+0300 (MSK))
datadir: /home/petrob/eth/data/node1
modules: admin:1.0 clique:1.0 debug:1.0 engine:1.0 eth:1.0 miner:1.0 net:1.0 rpc:1.0 txpool:1.0 web3:1.0

To exit, press ctrl-d or type exit
> net.peerCount
0
> admin.peers
[[{"caps": ["eth/68", "snap/1"],
  "enode": "//26524071a1ba67482c85c0f59007a5dd4fe366884d56bc3710df2e556d9936d5e8cd6dbaf8ba5945f4fc381d3e66c7e800102f6c0fa4ace827f8d6323f21da2c@172.18.244.175:33548",
  "id": "6f19fc27eea5518d3ad07001889f49f73bd568891d88cd97916410b0e773a95e",
  "name": "Geth/v1.15.11-stable-36b2371c/linux-amd64/go1.24.2",
  "network": {
    inbound: true,
    localAddress: "172.18.244.175:30306",
    remoteAddress: "172.18.244.175:33548",
    static: false,
    trusted: false
  },
  "protocols": {
    eth: {
      version: 68
    },
    snap: {
      version: 1
    }
  }
}], [{"caps": ["eth/68", "snap/1"],
  "enode": "//af645702a03a8c303f34444f152ca8f919fb40ead01d6e44015f54385a37f580960342fa54932206ae3dc35b542e12e9f260446bc8ed6b6ccdb94a4c8961ed9@172.18.244.175:38792",
  "id": "aee424aad849b11fbb6d9faa4a00788845ae9cbf7d771cb46ceecb489eee5b71",
  "name": "Geth/v1.15.11-stable-36b2371c/linux-amd64/go1.24.2",
  "network": {
    inbound: true,
    localAddress: "172.18.244.175:30306",
    remoteAddress: "172.18.244.175:38792",
    static: false,
    trusted: false
  },
  "protocols": {
    eth: {
      version: 68
    },
    snap: {
      version: 1
    }
  }
}]]
> eth.getBalance(eth.accounts[0])
1e+23
```

При запиті балансу на Clef надійшов запит на підтвердження доступу

```
----- List Account request-----
A request has been made to list all accounts.
You can select which accounts the caller can see
[x] 0x8376C437e12E0a9BDE2313634450f3b3b601c625
  URL: keystore:///home/petrob/eth/clef-merged-keystore/UTC--2025-06-04T14-03-29.958727838Z--8376c437e12e0a9bde2313634450f3b3b601c625
[x] 0xdFf1782f8cd2f99aCfc2F9a4Dcdba10b57DA7a2c
  URL: keystore:///home/petrob/eth/clef-merged-keystore/UTC--2025-06-04T14-03-54.431749475Z--dff1782f8cd2f99acfc2f9a4dcdba10b57da7a2c
[x] 0xE11D619851fA85AB201a93D0E1Db1E6e2d9d05F6
  URL: keystore:///home/petrob/eth/clef-merged-keystore/UTC--2025-06-04T14-04-06.624977039Z--e11d619851fa85ab201a93d0e1db1e6e2d9d05f6
-----

Request context:
NA -> ipc -> NA

Additional HTTP header data, provided by the external caller:
  User-Agent: ""
  Origin: ""
Approve? [y/N]:
> y
```

Такі запити надходитимуть за кожної транзакції, надалі не будемо на них відволікатися, окрім особливих випадків.

Аналогічне виконаємо та перевіримо для вузлів 2 та 3.

```

~/eth % geth attach data/node2/geth.ipc
Welcome to the Geth JavaScript console!

instance: Geth/v1.15.11-stable-36b2371c/linux-amd64/go1.24.2
at block: 0 (Thu Jan 01 1970 03:00:00 GMT+0300 (MSK))
datadir: /home/petrob/eth/data/node2
modules: admin:1.0 clique:1.0 debug:1.0 engine:1.0 eth:1.0 miner:1.0 net:1.0 rpc:1.0 txpool:1.0 web3:1.0

To exit, press ctrl-d or type exit
> admin.peers
[{}
  {
    caps: ["eth/68", "snap/1"],
    enode: "enode://7a7d3ee31a25127d3f27a9298801fc37d94179212f246b0f30f41080138b13966a3b2875f5b92a56bea7ef3f9ded77ae01ef648667f6b1775059ea7ef1985db76b172.18.244.175:30306",
    enr: "enr:-HDQGDHaetsvvV30M0wcyZ2kUsY0aArweG2wq52z3hiq2k0VpggJLj1fSxvyyuQkr5XageK-zg5NajjyYIG75TCGjagAZc77dImq2V0baHFGHd0B7-CageLignY0gmLwhHw59K-Jc2VjcD11NesxoQm6FT7JG1USFT8nq5CIAfa32UFS1S8ka8w9BCAEs1t0r",
    id: "4dd69990b315a6d8308643820b326ae8da8c7a828cf37e9c3fde3b67657785",
    name: "Geth/v1.15.11-stable-36b2371c/linux-amd64/go1.24.2",
    network: {
      inbound: false,
      localAddress: "172.18.244.175:39192",
      remoteAddress: "172.18.244.175:30306",
      static: false,
      trusted: false
    },
    protocols: {
      eth: {
        version: 68
      },
      snap: {
        version: 1
      }
    }
  }
]
> eth.getBalance(eth.accounts[1])
0x0

~/eth % geth attach data/node3/geth.ipc
Welcome to the Geth JavaScript console!

instance: Geth/v1.15.11-stable-36b2371c/linux-amd64/go1.24.2
at block: 0 (Thu Jan 01 1970 03:00:00 GMT+0300 (MSK))
datadir: /home/petrob/eth/data/node3
modules: admin:1.0 clique:1.0 debug:1.0 engine:1.0 eth:1.0 miner:1.0 net:1.0 rpc:1.0 txpool:1.0 web3:1.0

To exit, press ctrl-d or type exit
> admin.peers
[{}
  {
    caps: ["eth/68", "snap/1"],
    enode: "enode://7a7d3ee31a25127d3f27a9298801fc37d94179212f246b0f30f41080138b13966a3b2875f5b92a56bea7ef3f9ded77ae01ef648667f6b1775059ea7ef1985db76b172.18.244.175:30306",
    enr: "enr:-HDQGDHaetsvvV30M0wcyZ2kUsY0aArweG2wq52z3hiq2k0VpggJLj1fSxvyyuQkr5XageK-zg5NajjyYIG75TCGjagAZc77dImq2V0baHFGHd0B7-CageLignY0gmLwhHw59K-Jc2VjcD11NesxoQm6FT7JG1USFT8nq5CIAfa32UFS1S8ka8w9BCAEs1t0r",
    id: "4dd69990b315a6d8308643820b326ae8da8c7a828cf37e9c3fde3b67657785",
    name: "Geth/v1.15.11-stable-36b2371c/linux-amd64/go1.24.2",
    network: {
      inbound: false,
      localAddress: "172.18.244.175:55510",
      remoteAddress: "172.18.244.175:30306",
      static: false,
      trusted: false
    },
    protocols: {
      eth: {
        version: 68
      },
      snap: {
        version: 1
      }
    }
  }
]
> eth.getBalance(eth.accounts[2])
0x0

```

Так як ми використовуємо один і той самий менеджер ключів, в кожній із нод є інформація про ключі всіх акаунтів. Це значно спрощує виконання транзакцій. Для чистоти експерименту із кожної ноди ми будемо використовувати тільки відповідний їй гаманець, наприклад для ноди 2 відповідним буде другий гаманець (0xdFf1782f8cd2f99aCfC2F9a4Dcdba10b57DA7a2c).

## Спроба виконання транзакції

Спробуємо надіслати валюту із ноди2 (із другого акаунта) на ноду1 (на перший акаунт):

[illegible]

Так виглядало підтвердження транзакції у Clef:

```

----- Transaction request -----
to:      0x8376C437e12E0a9BDE2313634450f3b3b601c625
from:    0xdFf1782f8cd2f99aCfc2F9a4Dcdba10b57DA7a2c [checksum ok]
value:   100000000000000000000000000000000 wei
gas:     0x5208 (21000)
maxFeePerGas: 2001000000 wei
maxPriorityFeePerGas: 1000000 wei
nonce:   0x1 (1)
chainid: 0x14684c
Accesslist:

Request context:
    NA -> ipc -> NA

Additional HTTP header data, provided by the external caller:
    User-Agent: ""
    Origin: ""
-----
Approve? [y/N]:
> y
WARN [06-04|21:55:46.358] Key does not exist key=0xdFf1782f8cd2f99aCfc2F9a4Dcdba10b57DA7a2c
## Account password

Please enter the password for account 0xdFf1782f8cd2f99aCfc2F9a4Dcdba10b57DA7a2c
>
-----
Transaction signed:
{
  "type": "0x2",
  "chainId": "0x14684c",
  "nonce": "0x1",
  "to": "0x8376c437e12e0a9bde2313634450f3b3b601c625",
  "gas": "0x5208",
  "gasPrice": null,
  "maxPriorityFeePerGas": "0xf4240",
  "maxFeePerGas": "0x7744d640",
  "value": "0x152d02c7e14af6800000",
  "input": "0x",
  "accessList": [],
  "v": "0x0",
  "r": "0x733d0ac92fc7cf55ccd1b6119123283579a300f9d33dc96c4b130e2943510f0b",
  "s": "0x15857805f7d75c5693d370de43f6e40bee42dce6e12136c036bc1e2d6c79ca66",
  "yParity": "0x0",
  "hash": "0x3cc684a8013198c7f98fd06dae193669c5ebe074148eac09653ddf3beb8f658"
}

```

Транзакція в трейсі другого вузла:

```
[INFO [06-04|21:55:53.900] Submitted transaction hash=0x3cc684a8013190c7f98fd6dae193669c5ebe074148eac09653ddf3beb8f658 from=0xdFf1782f8cd2f99aCfC2F9a40cdba10b57DA7a2c nonce=1 recipient=0x8376c437e12Eba9BDE2313634450f3b3b601c625 value=100,000,000,000,000,000,000,000
```

### Транзакції в txpool:

```
> txpool
{
  content: {
    pending: {
      0xdFf1782f8cd2f99aCFc2F9a4Dcdba10b57DA7a2c: {
        0: {...},
        1: {...}
      }
    },
    queued: {}
  },
  inspect: {
    pending: {
      0xdFf1782f8cd2f99aCFc2F9a4Dcdba10b57DA7a2c: {
        0: "0x8376C437e12E0a9BDE2313634450f3b3b601c625: 5000 wei + 21000 gas x 2001000000 wei",
        1: "0x8376C437e12E0a9BDE2313634450f3b3b601c625: 1000000000000000000000000 wei + 21000 gas x 2001000000 wei"
      }
    },
    queued: {}
  },
  status: {
    pending: 2,
    queued: 0
  },
  contentFrom: function(),
  getContent: function(callback),
  getInspect: function(callback),
  getStatus: function(callback)
}
```

# Епопея зі спробою підняти beacon для коректної роботи PoS

PoA наразі є застарівшим для нашої версії Geth, а це означає, що для успішного створення блоку необхідно підняти beacon client.

**WARN [06-05|12:58:12.695] Post-merge network, but no beacon client seen. Please launch one to follow the chain!**

Але, на жаль, всі спроби імпортувати ключі та успішно синхронізувати beacon client не дали позитивного результату. Нам вдалося підключити beacon client та validator до головної ноди, але сам beacon не може виконати обчислення через порушену структуру ланцюга.

```
bazel run //cmd/beacon-chain --configrelease -- --execution-endpoints=/home/petrob/eth/data/node1/geth.ipc --chain-id 1337420 --force-clear-db
INFO: Analyzed target //cmd/beacon-chain:beacon-chain (0 packages loaded, 0 targets configured).
INFO: Found 1 target...
INFO: //cmd/beacon-chain:beacon-chain up-to-date:
  bazel-bin/cmd/beacon-chain/beacon-chain/beacon-chain
INFO: Elapsed time: 0.339s, Critical Path: 0.02s
INFO: 1 process: 1 internal.
INFO: Build completed successfully, 1 total action
INFO: Running command line: bazel-bin/cmd/beacon-chain/beacon-chain --execution-endpoints=/home/petrob/eth/data/node1/geth.ipc --chain-id 1337420 --force-clear-db
[2025-06-05 12:59:57] INFO flags: Running on Ethereum Mainnet
[2025-06-05 12:59:57] WARN node: In order to receive transaction fees from proposing blocks, you must provide flag --suggested-fee-recipient with a valid ethereum address when starting your beacon node. Please see our documentation for more information on this requirement (https://docs Prylabs network/docs/execution-node/fee-recipient).
[2025-06-05 12:59:57] INFO node: Checking DB database=/home/petrob/.eth2/beaconchaindata
[2025-06-05 12:59:57] INFO db: Opening Bolt DB path=/home/petrob/.eth2/beaconchaindata/beaconchain.db
[2025-06-05 12:59:57] WARN node: Removing database
[2025-06-05 12:59:57] INFO db: Opening Bolt DB path=/home/petrob/.eth2/beaconchaindata/beaconchain.db
[2025-06-05 12:59:57] INFO node: Deposit contract address=0x00000000219ab540356cd8893Cde8533027705Fa
[2025-06-05 12:59:57] INFO filesystem: Blob filesystem cache warm-up started. This may take a few minutes.
[2025-06-05 12:59:57] INFO filesystem: Blob filesystem cache warm-up complete. elapsed=68.391us
[2025-06-05 12:59:57] INFO p2p: Running node with peer id of 16Uiu2HAmJFzdURmH7ZrtURDUXFAIH9e7YCHntboGDP1uGUMgSa6n
[2025-06-05 12:59:57] INFO p2p: failed to sufficiently increase receive buffer size (max: 200 KiB, wanted: 7168 KiB, got: 416 KiB). See https://github.com/quic-go/quic-go/wiki/UDP-Buffer-Sizes for details.
[2025-06-05 13:00:00] INFO rpc: gRPC server listening on port address=127.0.0.1:8080
[2025-06-05 13:00:00] WARN rpc: You are using an insecure gRPC server. If you are running your beacon node and validator on the same machines, you can ignore this message. If you want to know how to enable secure connections, see: https://docs.prylabs.network/docs/prysm-usage/secure-grpc
[2025-06-05 13:00:00] INFO https://docs.prylabs.network/docs/prysm-usage/secure-grpc
[2025-06-05 13:00:00] INFO initial-sync: Waiting for state to be initialized
[2025-06-05 13:00:00] INFO blockchain: Blockchain data already exists in DB, initializing...
[2025-06-05 13:00:00] INFO backfill: Backfill service not enabled
[2025-06-05 13:00:00] INFO httprest: Starting HTTP server address=127.0.0.1:3500
[2025-06-05 13:00:00] ERROR state-gen: Could not clean up dirty states error=OriginBlockRoot: not found in db
[2025-06-05 13:00:00] INFO blockchain: Initialized head block from DB root=0x4d611d5b93fdab69013a7f6a2f961cacab8c853f87cfe9595fe50038163979360 slot=0
[2025-06-05 13:00:00] INFO initial-sync: Received state initialized event
[2025-06-05 13:00:00] INFO initial-sync: Starting initial chain sync...
[2025-06-05 13:00:00] INFO initial-sync: Waiting for enough suitable peers before syncing required=3 suitable=0
[2025-06-05 13:00:00] INFO p2p: Started discovery v5 ENR=enr:-MqQWincXl0chrGnUDubvF8Mw5u5KwMDGF3hG0weJDXLB2_xqoA7o-UHesZEhOPr4nj4FRqQpp66wJ62IZ3c-6GAZc_1IFqh2F0dGSldh0IAAAAAAAACEZXRoMPCtUyZrBgAAAP_galIgnYBgaLwHw5S9K-EckVpY4jYy1z2WmWjU2aGhA1LzYP5Sw2EfwT2RuZdWxMq927Fqa3CL0v8J7R3D1HNSbWmW2XR2A1NB3Y3CNs1dWmWg17g
[2025-06-05 13:00:00] INFO p2p: New node record enr:-MqQWincXl0chrGnUDubvF8Mw5u5KwMDGF3hG0weJDXLB2_xqoA7o-UHesZEhOPr4nj4FRqQpp66wJ62IZ3c-6GAZc_1IFqh2F0dGSldh0IAAAAAAAACEZXRoMPCtUyZrBgAAAP_galIgnYBgaLwHw5S9K-EckVpY4jYy1z2WmWjU2aGhA1LzYP5Sw2EfwT2RuZdWxMq927Fqa3CL0v8J7R3D1HNSbWmW2XR2A1NB3Y3CNs1dWmWg17g
[2025-06-05 13:00:00] INFO p2p: Node started p2p server multiAddr=/ip4/172.18.248.175/tcp/13800/p2p/16Uiu2HAmJFzdURmH7ZrtURDUXFAIH9e7YCHntboGDP1uGUMgSa6n
[2025-06-05 13:00:00] INFO rpc: gRPC client connected to beacon node address=127.0.0.1:8080
[2025-06-05 13:00:00] INFO initial-sync: Waiting for enough suitable peers before syncing required=3 suitable=1
[2025-06-05 13:00:15] INFO execution: Connected to new endpoint endpoint=***
[2025-06-05 13:01:00] INFO p2p: Connected peers inboundQUIC=0 inboundTCP=0 outboundQUIC=1 outboundTCP=6 total=7
[2025-06-05 13:01:10] INFO initial-sync: Processing blocks batchSize=49 blocksPerSecond=2.5 estimatedTimeRemaining=1344h25m19s latestProcessedSlot/currentSlot=1/11857803 peers=7 startingFrom=0xbacd20f9...
[2025-06-05 13:01:11] INFO initial-sync: Processing blocks batchSize=55 blocksPerSecond=5.2 estimatedTimeRemaining=633h25m34s latestProcessedSlot/currentSlot=65/11857804 peers=6 startingFrom=0x37c265d4...
[2025-06-05 13:01:12] INFO initial-sync: Processing blocks batchSize=52 blocksPerSecond=7.8 estimatedTimeRemaining=422h16m54s latestProcessedSlot/currentSlot=128/11857804 peers=6 startingFrom=0x94mb198a...
[2025-06-05 13:01:12] INFO initial-sync: Processing blocks batchSize=54 blocksPerSecond=10.8 estimatedTimeRemaining=313h41m36s latestProcessedSlot/currentSlot=192/11857804 peers=6 startingFrom=0x922728a1...
[2025-06-05 13:01:13] INFO initial-sync: Processing blocks batchSize=51 blocksPerSecond=13.1 estimatedTimeRemaining=252h22m46s latestProcessedSlot/currentSlot=256/11857804 peers=6 startingFrom=0x9cd9a904...
[2025-06-05 13:01:44] INFO initial-sync: Processing blocks batchSize=54 blocksPerSecond=2.7 estimatedTimeRemaining=1219h54m21s latestProcessedSlot/currentSlot=320/11857806 peers=6 startingFrom=0x76ed0a81...
[2025-06-05 12:57:19] WARN initial-sync: Skip processing batched blocks error=beacon node doesn't have a parent in db with root: 0x08568877ac3702a5fe48c1300903c67b79210f0ababaa2db2c6f589e99a996683 (in process batchedBlocks, slot=2385)
```

```
~/eth/prysm (v6.0.2) » bazel run //cmd/validator --configrelease
INFO: Analyzed target //cmd/validator:validator (0 packages loaded, 0 targets configured).
INFO: Found 1 target...
INFO: //cmd/validator:validator up-to-date:
  bazel-bin/cmd/validator/validator/validator
INFO: Elapsed time: 0.311s, Critical Path: 0.01s
INFO: 1 process: 1 internal.
INFO: Build completed successfully, 1 total action
INFO: Running command line: bazel-bin/cmd/validator/validator/validator
[2025-06-05 12:46:37] INFO flags: Running on Ethereum Mainnet
[2025-06-05 12:46:37] INFO userprompt: (wallet path) /home/petrob/.eth2/validators/prysm-wallet-v2
Wallet password:
[2025-06-05 12:46:42] INFO wallet: Opened validator wallet keymanagerV2indirect wallet=/home/petrob/.eth2/validators/prysm-wallet-v2/direct
[2025-06-05 12:46:42] INFO node: Checking DB database=/home/petrob/.eth2
Adding optimizations for validator slashing protection 100% [=====] [0s:0s]
[2025-06-05 12:46:42] WARN No proposer settings were provided
[2025-06-05 12:46:42] INFO client: Syncing with beacon node to align on chain genesis info
[2025-06-05 12:46:42] INFO client: Beacon chain started genesisTime=2025-12-01 14:00:23 +0200 EET
[2025-06-05 12:46:42] WARN local-keymanager: Starting without accounts located in wallet at /home/petrob/.eth2/validators/prysm-wallet-v2/direct/accounts/all-accounts.keystore.json
[2025-06-05 12:46:48] INFO client: Waiting for beacon node to sync to latest chain head
[2025-06-05 12:46:54] INFO client: Waiting for beacon node to sync to latest chain head
[2025-06-05 12:47:00] INFO client: Waiting for beacon node to sync to latest chain head
[2025-06-05 12:47:06] INFO client: Waiting for beacon node to sync to latest chain head
[2025-06-05 12:47:12] INFO client: Waiting for beacon node to sync to latest chain head
[2025-06-05 12:47:18] INFO client: Waiting for beacon node to sync to latest chain head
[2025-06-05 12:47:24] INFO client: Waiting for beacon node to sync to latest chain head
[2025-06-05 12:47:30] INFO client: Waiting for beacon node to sync to latest chain head
[2025-06-05 12:47:36] INFO client: Waiting for beacon node to sync to latest chain head
[2025-06-05 12:47:42] INFO client: Waiting for beacon node to sync to latest chain head
[2025-06-05 12:47:48] INFO client: Waiting for beacon node to sync to latest chain head
[2025-06-05 12:47:54] INFO client: Waiting for beacon node to sync to latest chain head
[2025-06-05 12:48:00] INFO client: Waiting for beacon node to sync to latest chain head
[2025-06-05 12:48:06] INFO client: Waiting for beacon node to sync to latest chain head
[2025-06-05 12:48:12] INFO client: Waiting for beacon node to sync to latest chain head
```

## Висновок

Нам вдалося розгорнути локальну p2p мережу Ethereum та виконати базові транзакції та переглянути їх в пулі транзакцій. Але ми зіштовхнулися із проблемою налаштування консенсусу PoS, через яку так і не вдалося синхронізувати ноди та згенерувати блок.

В ході лабораторної роботи ми все ж змогли більш-менш детально розібратися, як працює мережа Ethereum, які в ній є параметри і особливості та як її налаштовувати. Ми зіштовхувалися із різними труднощами, як при створенні нод, проведенні транзакцій, так і з найбільшою перепорою – налаштування клієнта для консенсуса.

## Список використаних команд

```
`mkdir data/node1 data/node2 data/node3`
```

```
geth --datadir data/node1 account new
```

```
geth --datadir data/node2 account new
```

```
geth --datadir data/node3 account new
```

```
0x8376C437e12E0a9BDE2313634450f3b3b601c625
```

```
0xdFf1782f8cd2f99aCFc2F9a4Dcdba10b57DA7a2c
```

```
0xE11D619851fA85AB201a93D0E1Db1E6e2d9d05F6
```

```
geth init --datadir data/node1 genesis.json
```

```
geth init --datadir data/node2 genesis.json
```

```
geth init --datadir data/node3 genesis.json
```

```
touch data/node1/password.txt
```

```
touch data/node2/password.txt
```

```
touch data/node3/password.txt
```

```
clef --keystore data/node1/keystore
```

```
clef --keystore data/node2/keystore
```

```
clef --keystore data/node3/keystore
```

```
clef --keystore clef-merged-keystore --chainid 1337420
```

```
/home/petrob/.clef/clef.ipc
```

bootnode:

```
geth --datadir data/node1 --networkid 1337420 --nat extip:172.18.244.175 --port 30306 --  
authrpc.port 8551 --mine --miner.etherbase 0x8376C437e12E0a9BDE2313634450f3b3b601c625 --  
signer /home/petrob/.clef/clef.ipc --http.api "eth,net,web3,clique,txpool"
```



```
bazel run //cmd/beacon-chain --config=release -- --execution-  
endpoint=/home/petrob/eth/data/node1/geth.ipc --chain-id 1337420
```

```
geth attach --exec admin.nodeInfo.enr data/node1/geth.ipc
```

other nodes:

```
geth --datadir data/node2 --networkid 1337420 --nat extip:172.18.244.175 --bootnodes "enr:-  
KO4QDMAetsvvYJ0MOWcyZT2kUsXMoArmeGZwqS2z3hiq2KkYpgzLMjIF5xvyuuQkrSXwgoK-  
zg5NmjyYIG75TC2GjaGAZc77dKmg2V0aMfGhDdB7-CAgmlkgnY0gmlwhKwS9K-  
Jc2VjcDI1NmsxoQN6fT7jGiUSfT8nqSCIAfw32UF5IS8ka48w9BCAE4sTloRzbmFwwIN0Y3CCdmKDdWR  
wgnZi" --port 30307 --authrpc.port 8552 --mine --miner.etherbase  
0xdFf1782f8cd2f99aCFc2F9a4Dcdba10b57DA7a2c --signer /home/petrob/.clef/clef.ipc
```

```
geth --datadir data/node3 --networkid 1337420 --nat extip:172.18.244.175 --bootnodes "enr:-  
KO4QDMAetsvvYJ0MOWcyZT2kUsXMoArmeGZwqS2z3hiq2KkYpgzLMjIF5xvyuuQkrSXwgoK-  
zg5NmjyYIG75TC2GjaGAZc77dKmg2V0aMfGhDdB7-CAgmlkgnY0gmlwhKwS9K-  
Jc2VjcDI1NmsxoQN6fT7jGiUSfT8nqSCIAfw32UF5IS8ka48w9BCAE4sTloRzbmFwwIN0Y3CCdmKDdWR  
wgnZi" --port 30308 --authrpc.port 8553 --mine --miner.etherbase  
0xE11D619851fA85AB201a93D0E1Db1E6e2d9d05F6 --signer /home/petrob/.clef/clef.ipc
```

console:

```
geth attach data/node1/geth.ipc
```

```
geth attach data/node2/geth.ipc
```

```
geth attach data/node3/geth.ipc
```

```
net.peerCount
```

```
admin.peers
```

```
eth.getBalance(eth.accounts[0])
```

```
eth.sendTransaction({  
  to: '0xE11D619851fA85AB201a93D0E1Db1E6e2d9d05F6',  
  from: eth.accounts[0],  
  value: 1000000000
```

```
});
```

```
geth --datadir data/node2 --networkid 1337420 --bootnodes  
"enode://a8514cb2afcb06f03a9c4e54f0d526548b79361f336b6413fbfd13acc58e686907ae73376867  
2477579514546f632094c0b69e7d1069604d76faef50ae573a63@127.0.0.1:0?discport=30305" --port  
30307 --unlock 0xdFf1782f8cd2f99aCFc2F9a4Dcdba10b57DA7a2c --password  
data/node2/password.txt --authrpc.port 8552 --mine --miner.etherbase  
0xdFf1782f8cd2f99aCFc2F9a4Dcdba10b57DA7a2c
```

```
geth --datadir data/node3 --networkid 1337420 --bootnodes  
"enode://a8514cb2afcb06f03a9c4e54f0d526548b79361f336b6413fbfd13acc58e686907ae73376867  
2477579514546f632094c0b69e7d1069604d76faef50ae573a63@127.0.0.1:0?discport=30305" --port  
30308 --unlock 0xE11D619851fA85AB201a93D0E1Db1E6e2d9d05F6 --password  
data/node3/password.txt --authrpc.port 8553 --mine --miner.etherbase  
0xE11D619851fA85AB201a93D0E1Db1E6e2d9d05F6
```