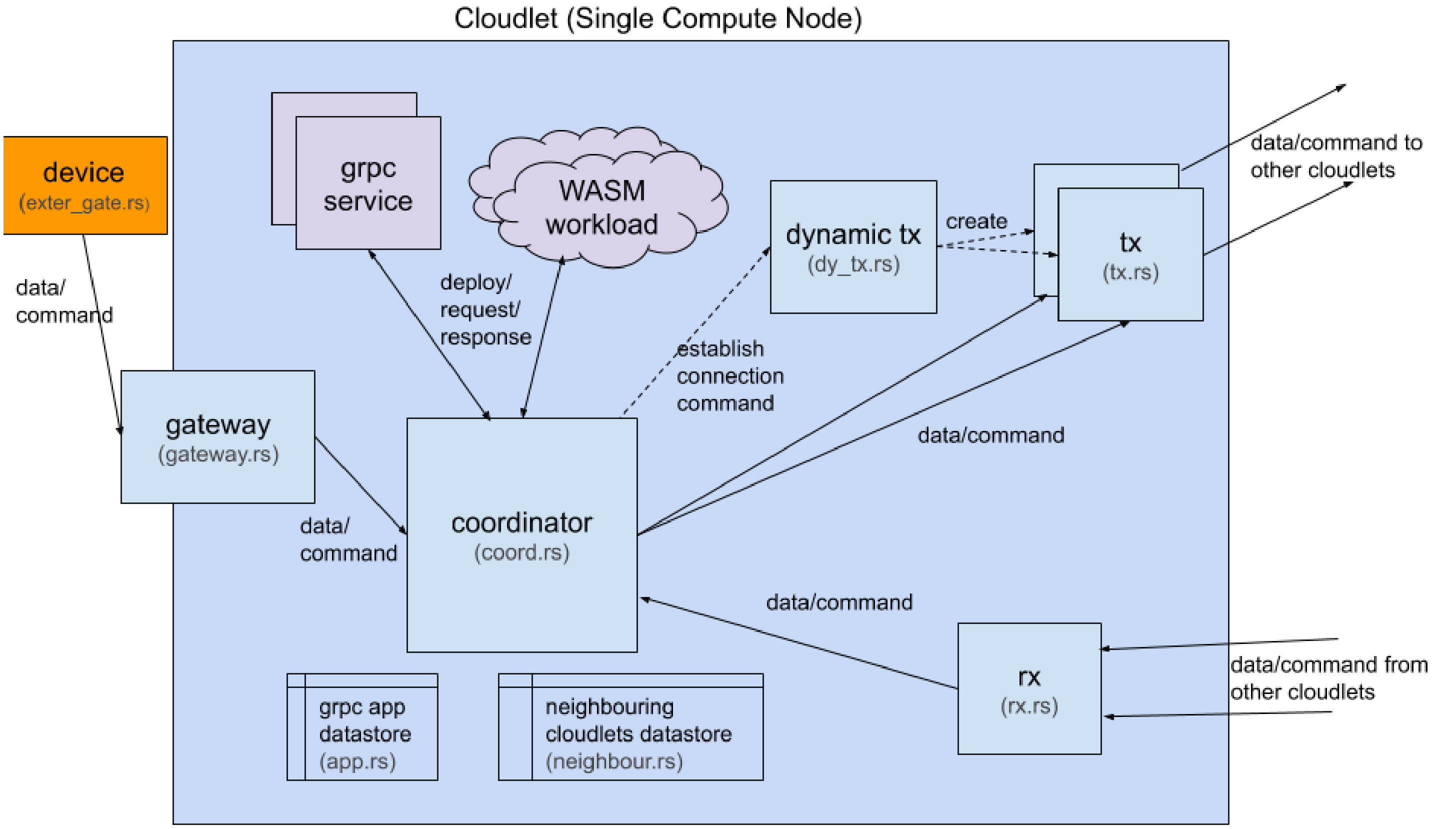
FogSys Architecture:



DEPLOYMENT ON HPC (CARC):

Steps:

1. **install GRPC for C++**
2. **install rust**
3. **compile fogsys**
4. **demo fogsys on HPC using 2 nodes with WASM and GRPC workload**

----

1. **INSTALL GRPC for C++ :**

reference: (https://grpc.io/docs/languages/cpp/quickstart/)

```
cd $HOME
export MY_INSTALL_DIR=$HOME/.local
mkdir -p $MY_INSTALL_DIR
export PATH="$PATH:$MY_INSTALL_DIR/bin"
module load gcc cmake llvm usc
git clone --recurse-submodules -b v1.34.0 https://github.com/grpc/grpc
cd grpc
```

mkdir -p cmake/build
pushd cmake/build
cmake -DgRPC_INSTALL=ON -DgRPC_BUILD_TESTS=OFF
-DCMAKE_INSTALL_PREFIX=$MY_INSTALL_DIR ../..
make
make install
popd

1.1 CREATE executable server_fib (fibonacci demo app) :

cd $HOME/grpc/examples/cpp/helloworld/

add “server_fib” in CMakeLists.txt after line 150:

add in Makefile after line 41:

```
server_fib: helloworld.pb.o helloworld.grpc.pb.o server_fib.o
    $(CXX) $^ $(LDFLAGS) -o $@
```

create server_fib.cc :

```
/*
*
* Copyright 2015 gRPC authors.
*
* Licensed under the Apache License, Version 2.0 (the "License");
* you may not use this file except in compliance with the License.
* You may obtain a copy of the License at
*
*     http://www.apache.org/licenses/LICENSE-2.0
*
* Unless required by applicable law or agreed to in writing, software
* distributed under the License is distributed on an "AS IS" BASIS,
* WITHOUT WARRANTIES OR CONDITIONS OF ANY KIND, either express or implied.
* See the License for the specific language governing permissions and
* limitations under the License.
*
*/

#include <iostream>
#include <memory>
```

```
#include <string>

#include <grpcpp/grpcpp.h>
#include <grpcpp/health_check_service_interface.h>
#include <grpcpp/ext/proto_server_reflection_plugin.h>

#ifdef BAZEL_BUILD
#include "examples/protos/helloworld.grpc.pb.h"
#else
#include "helloworld.grpc.pb.h"
#endif

using grpc::Server;
using grpc::ServerBuilder;
using grpc::ServerContext;
using grpc::Status;
using helloworld::HelloRequest;
using helloworld::HelloReply;
using helloworld::Greeter;

// Logic and data behind the server's behavior.

int fib(int n) {
   if (n<0)
       {printf("Incorrect input");}

   else if( n==0){
       return 0;}
    else if( n==1){
       return 1;}
   else {
       return fib(n-1)+fib(n-2) ;}

}



class GreeterServiceImpl final : public Greeter::Service {
 Status SayHello(ServerContext* context, const HelloRequest* request,
                 HelloReply* reply) override {
```

```
                 //  std::cout << "servering" <<  std::endl;
int num1 = stoi(request->name());

           std::string f_str = std::to_string(fib(num1));
   // std::string prefix(fib());
   // reply->set_message(prefix + request->name());
   reply->set_message(f_str);
   return Status::OK;
 }
};

void RunServer() {
 std::string server_address("127.0.0.1:50051");
 GreeterServiceImpl service;

 grpc::EnableDefaultHealthCheckService(true);
 grpc::reflection::InitProtoReflectionServerBuilderPlugin();
 ServerBuilder builder;
 // Listen on the given address without any authentication mechanism.
 builder.AddListeningPort(server_address,
grpc::InsecureServerCredentials());
 // Register "service" as the instance through which we'll communicate
with
 // clients. In this case it corresponds to an *synchronous* service.
 builder.RegisterService(&service);
 // Finally assemble the server.
 std::unique_ptr<Server> server(builder.BuildAndStart());
 // std::cout << "Server listening onn " << server_address << std::endl;

 // Wait for the server to shutdown. Note that some other thread must be
 // responsible for shutting down the server for this call to ever return.
 server->Wait();
}

int main(int argc, char** argv) {
 RunServer();

 return 0;
}
```

[redacted]

```
cd $HOME/grpc/examples/cpp/helloworld/
mkdir -p cmake/build
pushd cmake/build
cmake -DCMAKE_PREFIX_PATH=$MY_INSTALL_DIR ../..
make server_fib
```

you should see executable “server_fib” in $HOME/grpc/examples/cpp/helloworld/cmake/build

----

2. **INSTALL RUST:**

reference: (https://www.rust-lang.org/tools/install)

```
curl --proto '=https' --tlsv1.2 -sSf https://sh.rustup.rs | sh
```

----

3. **COMPILE fogsys:**

```
mkdir -p $HOME/rust
cd $HOME/rust

git clone https://github.com/hawkw/tonic.git
cd tonic
git checkout eliza/tokio-0.3
cd $HOME/rust
git clone https://github.com/chen116/fogsys
cd fogsys
cargo fetch
```

create a slurm file (fogsys.sl) in $HOME

```
//////////////////////////////////////////////////////////////
#!/bin/bash

#SBATCH --nodes=2
#SBATCH --ntasks=2
#SBATCH --cpus-per-task=2
#SBATCH --time=1:00:00
#SBATCH --account=jpwalter_148( not sure what account is available for u guys )

nodes=$(scontrol show hostnames "${SLURM_JOB_NODELIST}")
echo $nodes

while true
```

```
do
   #echo "Press [CTRL+C] to stop.."
   sleep 1000
done
//////////////////////////////////////////////////////////////////
```

To submit a job with fogsys.sl:

```
sbatch fogsys.sl
```

once the job start running, ssh into any of the two nodes, you can know which nodes are allocated to your job using one of the following two ways:

```
squeue -u $YOUR_ACCOUNT_NAME
```

or
read the slurm job log file

after logged into a compute node:

```
cd $HOME/rust/fogsys
cargo build
```

after a while, fogsys should be built successfully.
----

4. TO RUN Fogsys:

run a slurm job with 2 nodes, let’s say now you have node e22-15 and e22-16,
lets label e22-15 as node A, e22-16 as node B

open 4 ssh windows to HPC, label them A1, A2, B1,B2
in A1 and A2:

```
ssh e22-15
```

in B1 and B2:

```
ssh e22-16
```

in A1:

```
module load llvm      (this is for hosting grpc service later )
```

for all 4 windows:

```
cd $HOME/rust/fogsys
```

Initialization:

in A1, B1:

```
cargo run --bin main -- --env HPC
```

after “main” started in A1,B1:

in A2:
```
cargo run --bin exter_gate -- --host e22-15
```
in B2:
```
cargo run --bin exter_gate -- --host e22-16
```

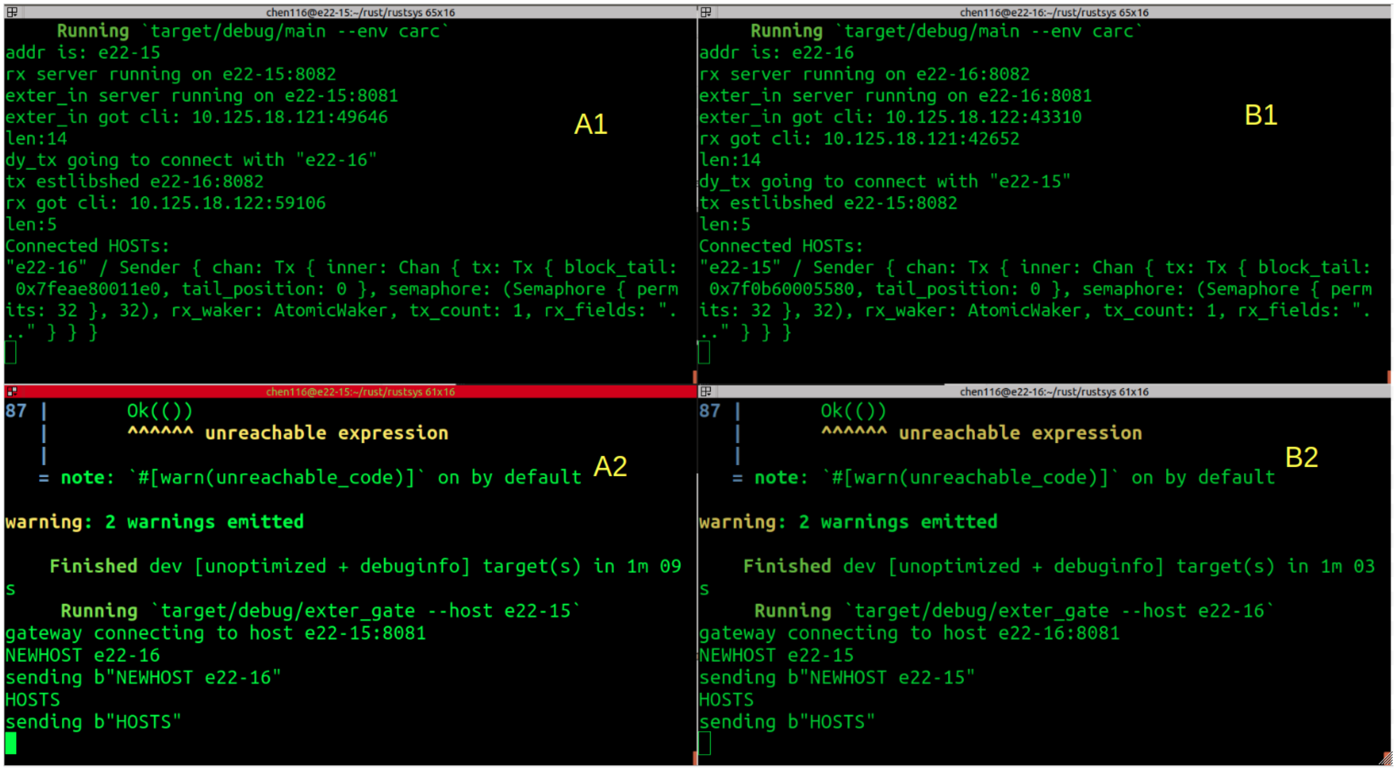
done initialization (cloudlets deployed in e22-15, e22-16)

now to connect two cloudlets:

in A2:
```
NEWHOST e22-16
```
in B2:
```
NEWHOST e22-15
```

to check if connected:
in A2:
```
HOSTS
```
in B2:
```
HOSTS
```

you should see in A1,B1 where they list out the connected neighbours



chen116@e22-15:~/rust/rustsys 65x16

```
     Running `target/debug/main --env carc`
addr is: e22-15
rx server running on e22-15:8082
exter_in server running on e22-15:8081
exter_in got cli: 10.125.18.121:49646
len:14
dy_tx going to connect with "e22-16"
tx estlibshed e22-16:8082
rx got cli: 10.125.18.122:59106
len:5
Connected HOSTs:
"e22-16" / Sender { chan: Tx { inner: Chan { tx: Tx { block_tail:
 0x7feae80011e0, tail_position: 0 }, semaphore: (Semaphore { perm
its: 32 }, 32), rx_waker: AtomicWaker, tx_count: 1, rx_fields: ".
.." } } }
```

chen116@e22-16:~/rust/rustsys 65x16

```
     Running `target/debug/main --env carc`
addr is: e22-16
rx server running on e22-16:8082
exter_in server running on e22-16:8081
exter_in got cli: 10.125.18.122:43310
rx got cli: 10.125.18.121:42652
len:14
dy_tx going to connect with "e22-15"
tx estlibshed e22-15:8082
len:5
Connected HOSTs:
"e22-15" / Sender { chan: Tx { inner: Chan { tx: Tx { block_tail:
 0x7f0b60005580, tail_position: 0 }, semaphore: (Semaphore { perm
its: 32 }, 32), rx_waker: AtomicWaker, tx_count: 1, rx_fields: ".
.." } } }
```

chen116@e22-15:~/rust/rustsys 61x16

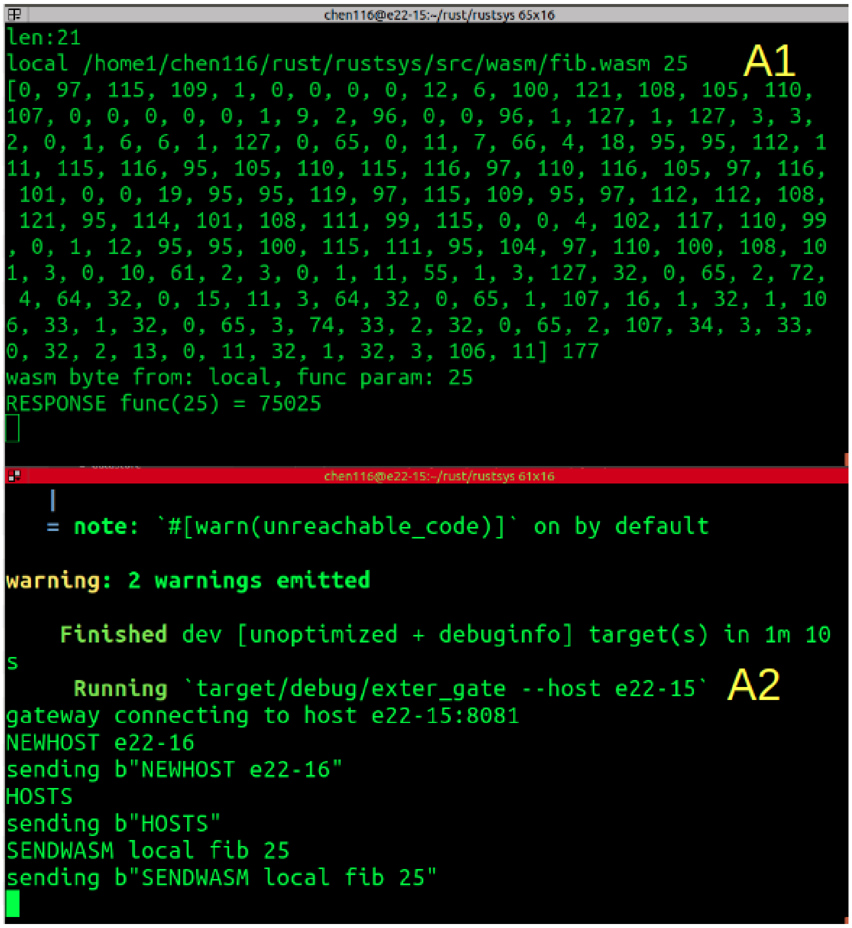
```
87 |         Ok(())
   |         ^^^^^^ unreachable expression
   |
   = note: `#[warn(unreachable_code)]` on by default

warning: 2 warnings emitted

    Finished dev [unoptimized + debuginfo] target(s) in 1m 09
s
     Running `target/debug/exter_gate --host e22-15`
gateway connecting to host e22-15:8081
NEWHOST e22-16
sending b"NEWHOST e22-16"
HOSTS
sending b"HOSTS"
```

chen116@e22-16:~/rust/rustsys 61x16

```
87 |         Ok(())
   |         ^^^^^^ unreachable expression
   |
   = note: `#[warn(unreachable_code)]` on by default

warning: 2 warnings emitted

    Finished dev [unoptimized + debuginfo] target(s) in 1m 03
s
     Running `target/debug/exter_gate --host e22-16`
gateway connecting to host e22-16:8081
NEWHOST e22-15
sending b"NEWHOST e22-15"
HOSTS
sending b"HOSTS"
```

webassembly demo:

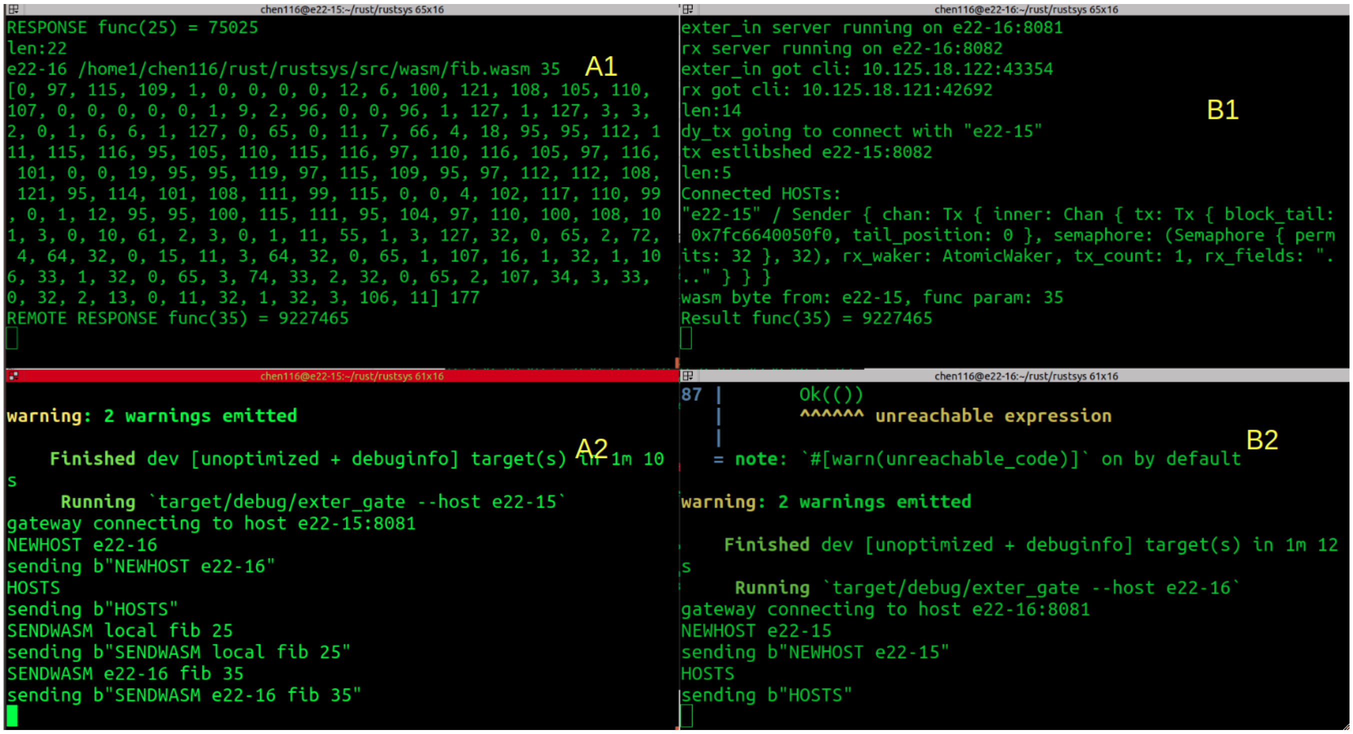
in A2:
SENDWASM local fib 25
(see response in A1)



```
len:21
local /home1/chen116/rust/rustsys/src/wasm/fib.wasm 25
[0, 97, 115, 109, 1, 0, 0, 0, 0, 12, 6, 100, 121, 108, 105, 110,
107, 0, 0, 0, 0, 0, 1, 9, 2, 96, 0, 0, 96, 1, 127, 1, 127, 3, 3,
2, 0, 1, 6, 6, 1, 127, 0, 65, 0, 11, 7, 66, 4, 18, 95, 95, 112, 1
11, 115, 116, 95, 105, 110, 115, 116, 97, 110, 116, 105, 97, 116,
 101, 0, 0, 19, 95, 95, 119, 97, 115, 109, 95, 97, 112, 112, 108,
 121, 95, 114, 101, 108, 111, 99, 115, 0, 0, 4, 102, 117, 110, 99
, 0, 1, 12, 95, 95, 100, 115, 111, 95, 104, 97, 110, 100, 108, 10
1, 3, 0, 10, 61, 2, 3, 0, 1, 11, 55, 1, 3, 127, 32, 0, 65, 2, 72,
 4, 64, 32, 0, 15, 11, 3, 64, 32, 0, 65, 1, 107, 16, 1, 32, 1, 10
6, 33, 1, 32, 0, 65, 3, 74, 33, 2, 32, 0, 65, 2, 107, 34, 3, 33,
0, 32, 2, 13, 0, 11, 32, 1, 32, 3, 106, 11] 177
wasm byte from: local, func param: 25
RESPONSE func(25) = 75025
```

```
    |
    = note: `#[warn(unreachable_code)]` on by default

warning: 2 warnings emitted

    Finished dev [unoptimized + debuginfo] target(s) in 1m 10
s
     Running `target/debug/exter_gate --host e22-15`
gateway connecting to host e22-15:8081
NEWHOST e22-16
sending b"NEWHOST e22-16"
HOSTS
sending b"HOSTS"
SENDWASM local fib 25
sending b"SENDWASM local fib 25"
```

in A2:
SENDWASM e22-16 fib 35
(see response in A1)


chen116@e22-15:~/rust/rustsys 65x16
A1
chen116@e22-16:~/rust/rustsys 65x16
B1
chen116@e22-15:~/rust/rustsys 61x16
A2
chen116@e22-16:~/rust/rustsys 61x16
B2

```
RESPONSE func(25) = 75025
len:22
e22-16 /home1/chen116/rust/rustsys/src/wasm/fib.wasm 35
[0, 97, 115, 109, 1, 0, 0, 0, 0, 12, 6, 100, 121, 108, 105, 110,
107, 0, 0, 0, 0, 0, 1, 9, 2, 96, 0, 0, 96, 1, 127, 1, 127, 3, 3,
2, 0, 1, 6, 6, 1, 127, 0, 65, 0, 11, 7, 66, 4, 18, 95, 95, 112, 1
11, 115, 116, 95, 105, 110, 115, 116, 97, 110, 116, 105, 97, 116,
 101, 0, 0, 19, 95, 95, 119, 97, 115, 109, 95, 97, 112, 112, 108,
 121, 95, 114, 101, 108, 111, 99, 115, 0, 0, 4, 102, 117, 110, 99
, 0, 1, 12, 95, 95, 100, 115, 111, 95, 104, 97, 110, 100, 108, 10
1, 3, 0, 10, 61, 2, 3, 0, 1, 11, 55, 1, 3, 127, 32, 0, 65, 2, 72,
 4, 64, 32, 0, 15, 11, 3, 64, 32, 0, 65, 1, 107, 16, 1, 32, 1, 10
6, 33, 1, 32, 0, 65, 3, 74, 33, 2, 32, 0, 65, 2, 107, 34, 3, 33,
0, 32, 2, 13, 0, 11, 32, 1, 32, 3, 106, 11] 177
REMOTE RESPONSE func(35) = 9227465
```

```
exter_in server running on e22-16:8081
rx server running on e22-16:8082
exter_in got cli: 10.125.18.122:43354
rx got cli: 10.125.18.121:42692
len:14
dy_tx going to connect with "e22-15"
tx estlibshed e22-15:8082
len:5
Connected HOSTs:
"e22-15" / Sender { chan: Tx { inner: Chan { tx: Tx { block_tail:
 0x7fc6640050f0, tail_position: 0 }, semaphore: (Semaphore { perm
its: 32 }, 32), rx_waker: AtomicWaker, tx_count: 1, rx_fields: ".
.." } } }
wasm byte from: e22-15, func param: 35
Result func(35) = 9227465
```

```

warning: 2 warnings emitted

    Finished dev [unoptimized + debuginfo] target(s) in 1m 10
s
     Running `target/debug/exter_gate --host e22-15`
gateway connecting to host e22-15:8081
NEWHOST e22-16
sending b"NEWHOST e22-16"
HOSTS
sending b"HOSTS"
SENDWASM local fib 25
sending b"SENDWASM local fib 25"
SENDWASM e22-16 fib 35
sending b"SENDWASM e22-16 fib 35"
```

```
87 |         Ok(())
   |         ^^^^^^ unreachable expression
   |
   = note: `#[warn(unreachable_code)]` on by default

warning: 2 warnings emitted

    Finished dev [unoptimized + debuginfo] target(s) in 1m 12
s
     Running `target/debug/exter_gate --host e22-16`
gateway connecting to host e22-16:8081
NEWHOST e22-15
sending b"NEWHOST e22-15"
HOSTS
sending b"HOSTS"
```

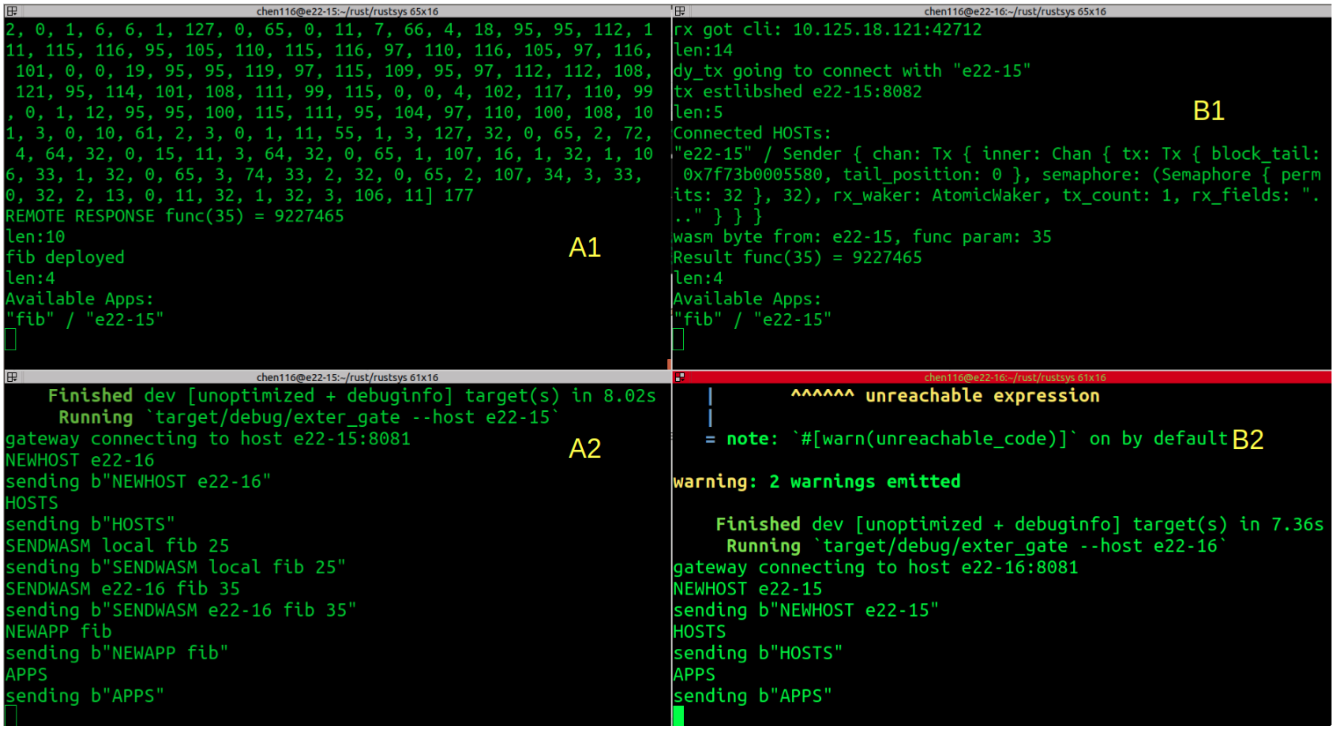
GRPC demo:

deploy a grpc service (server_fib) in node A (e22-15):

in A2:
NEWAPP fib

to check if fib app is deployed and available for both cloudlets
in both A2, B2:
APPS

you should see “fib” as available apps in A1/B1


chen116@e22-15:~/rust/rustsys 65x16
chen116@e22-16:~/rust/rustsys 65x16
chen116@e22-15:~/rust/rustsys 61x16
chen116@e22-16:~/rust/rustsys 61x16
A1
B1
A2
B2

```
2, 0, 1, 6, 6, 1, 127, 0, 65, 0, 11, 7, 66, 4, 18, 95, 95, 112, 1
11, 115, 116, 95, 105, 110, 115, 116, 97, 110, 116, 105, 97, 116,
 101, 0, 0, 19, 95, 95, 119, 97, 115, 109, 95, 97, 112, 112, 108,
 121, 95, 114, 101, 108, 111, 99, 115, 0, 0, 4, 102, 117, 110, 99
, 0, 1, 12, 95, 95, 100, 115, 111, 95, 104, 97, 110, 100, 108, 10
1, 3, 0, 10, 61, 2, 3, 0, 1, 11, 55, 1, 3, 127, 32, 0, 65, 2, 72,
 4, 64, 32, 0, 15, 11, 3, 64, 32, 0, 65, 1, 107, 16, 1, 32, 1, 10
6, 33, 1, 32, 0, 65, 3, 74, 33, 2, 32, 0, 65, 2, 107, 34, 3, 33,
0, 32, 2, 13, 0, 11, 32, 1, 32, 3, 106, 11] 177
REMOTE RESPONSE func(35) = 9227465
len:10
fib deployed
len:4
Available Apps:
"fib" / "e22-15"
```

```
rx got cli: 10.125.18.121:42712
len:14
dy_tx going to connect with "e22-15"
tx estlibshed e22-15:8082
len:5
Connected HOSTs:
"e22-15" / Sender { chan: Tx { inner: Chan { tx: Tx { block_tail:
 0x7f73b0005580, tail_position: 0 }, semaphore: (Semaphore { perm
its: 32 }, 32), rx_waker: AtomicWaker, tx_count: 1, rx_fields: ".
.." } } }
wasm byte from: e22-15, func param: 35
Result func(35) = 9227465
len:4
Available Apps:
"fib" / "e22-15"
```

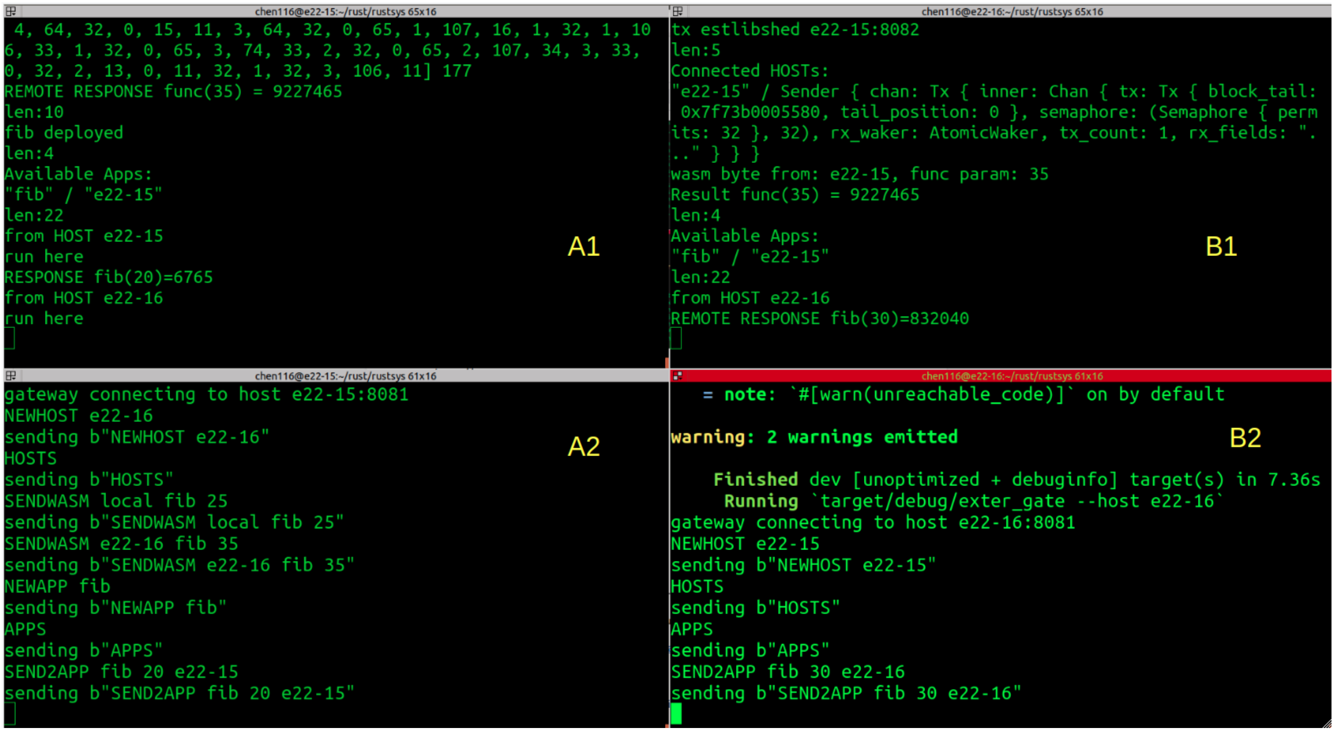
```
    Finished dev [unoptimized + debuginfo] target(s) in 8.02s
     Running `target/debug/exter_gate --host e22-15`
gateway connecting to host e22-15:8081
NEWHOST e22-16
sending b"NEWHOST e22-16"
HOSTS
sending b"HOSTS"
SENDWASM local fib 25
sending b"SENDWASM local fib 25"
SENDWASM e22-16 fib 35
sending b"SENDWASM e22-16 fib 35"
NEWAPP fib
sending b"NEWAPP fib"
APPS
sending b"APPS"
```

```
   |        ^^^^^^ unreachable expression
   |
   = note: `#[warn(unreachable_code)]` on by default

warning: 2 warnings emitted

    Finished dev [unoptimized + debuginfo] target(s) in 7.36s
     Running `target/debug/exter_gate --host e22-16`
gateway connecting to host e22-16:8081
NEWHOST e22-15
sending b"NEWHOST e22-15"
HOSTS
sending b"HOSTS"
APPS
sending b"APPS"
```

to use the fib grpc app:

in A2:
SEND2APP fib 20 e22-15
(see response in A1)

in B2:
SEND2APP fib 30 e22-16
(see response in B1)


chen116@e22-15:~/rust/rustsys 65x16
A1
chen116@e22-16:~/rust/rustsys 65x16
B1
chen116@e22-15:~/rust/rustsys 61x16
A2
chen116@e22-16:~/rust/rustsys 61x16
B2

```
 4, 64, 32, 0, 15, 11, 3, 64, 32, 0, 65, 1, 107, 16, 1, 32, 1, 10
6, 33, 1, 32, 0, 65, 3, 74, 33, 2, 32, 0, 65, 2, 107, 34, 3, 33,
0, 32, 2, 13, 0, 11, 32, 1, 32, 3, 106, 11] 177
REMOTE RESPONSE func(35) = 9227465
len:10
fib deployed
len:4
Available Apps:
"fib" / "e22-15"
len:22
from HOST e22-15
run here
RESPONSE fib(20)=6765
from HOST e22-16
run here
```

```
tx estlibshed e22-15:8082
len:5
Connected HOSTs:
"e22-15" / Sender { chan: Tx { inner: Chan { tx: Tx { block_tail:
 0x7f73b0005580, tail_position: 0 }, semaphore: (Semaphore { perm
its: 32 }, 32), rx_waker: AtomicWaker, tx_count: 1, rx_fields: ".
.." } } }
wasm byte from: e22-15, func param: 35
Result func(35) = 9227465
len:4
Available Apps:
"fib" / "e22-15"
len:22
from HOST e22-16
REMOTE RESPONSE fib(30)=832040
```

```
gateway connecting to host e22-15:8081
NEWHOST e22-16
sending b"NEWHOST e22-16"
HOSTS
sending b"HOSTS"
SENDWASM local fib 25
sending b"SENDWASM local fib 25"
SENDWASM e22-16 fib 35
sending b"SENDWASM e22-16 fib 35"
NEWAPP fib
sending b"NEWAPP fib"
APPS
sending b"APPS"
SEND2APP fib 20 e22-15
sending b"SEND2APP fib 20 e22-15"
```

```
   = note: `#[warn(unreachable_code)]` on by default

warning: 2 warnings emitted

    Finished dev [unoptimized + debuginfo] target(s) in 7.36s
     Running `target/debug/exter_gate --host e22-16`
gateway connecting to host e22-16:8081
NEWHOST e22-15
sending b"NEWHOST e22-15"
HOSTS
sending b"HOSTS"
APPS
sending b"APPS"
SEND2APP fib 30 e22-16
sending b"SEND2APP fib 30 e22-16"
```

INSTALL emscripten (for compiling code to wasm)
(i install emscripten on my laptop ubuntu 18.04)

https://emscripten.org/docs/getting_started/downloads.html

to compile c file to standalone wasm:

emcc -O2 -s WASM=1 -s SIDE_MODULE=1 -o fib.wasm fib.c

now fib.wasm can be used in fogsys

(see fogsys/src/bin/wasm* for examples, to run : cargo run --bin wasmtime_example)
