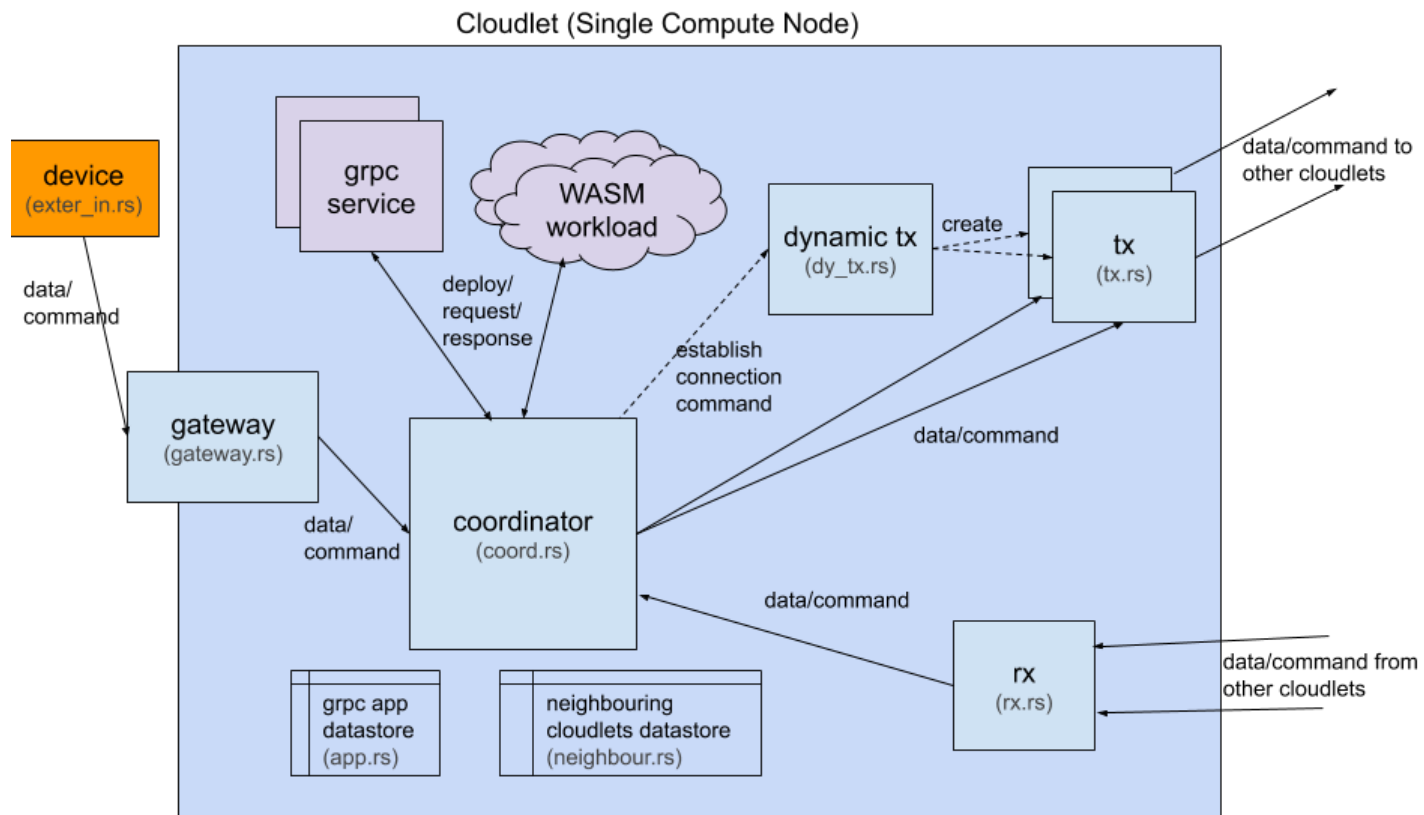


FogSys Architecture:



DEPLOYMENT ON CARC:

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:$MY_INSTALL_DIR/bin"
module load gcc cmake llvm usc
git clone --recurse-submodules -b v1.34.0 https://github.com/grpc/grpc
cd grpc
mkdir -p cmake/build
pushd cmake/build
cmake -DgRPC_INSTALL=ON -DgRPC_BUILD_TESTS=OFF
-DMAKE_INSTALL_PREFIX=$MY_INSTALL_DIR ../..
make
make install
popd
```

CREATE executable server_fib (fibonacci demo app) :

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

add "server_fib" in CMakeLists.txt after line 150:

add

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

in Makefile after line 41.

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;
}

```

```
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

INSTALL RUST:

reference: (<https://www.rust-lang.org/tools/install>)
curl --proto '=https' --tlsv1.2 -sSf https://sh.rustup.rs | sh

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.

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 CARC, 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 carc
```

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)

```
chen116@e22-15:~/rust/rustsys 65x16
len:21
local /home1/chen116/rust/rustsys/src/wasm/fib.wasm 25 A1
[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

chen116@e22-15:~/rust/rustsys 61x16
|
= note: `[warn(unreachable_code)]` on by default
warning: 2 warnings emitted

Finished dev [unoptimized + debuginfo] target(s) in 1m 10s
Running `target/debug/exter_gate --host e22-15` A2
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
RESPONSE func(25) = 75025
len:22
e22-16 /home1/chen116/rust/rustsys/src/wasm/fib.wasm 35 A1
[0, 97, 115, 109, 1, 0, 0, 0, 12, 6, 100, 121, 108, 105, 110,
107, 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

chen116@e22-15:~/rust/rustsys 61x16
warning: 2 warnings emitted
Finished dev [unoptimized + debuginfo] target(s) in 1m 10s
Running `target/debug/extergate --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"

chen116@e22-16:~/rust/rustsys 65x16
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 B1
dy_tx going to connect with "e22-15"
tx established 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

chen116@e22-16:~/rust/rustsys 61x16
87 | Ok(())
| ^^^^^^ unreachable expression B2
= note: `[warn(unreachable_code)]` on by default
warning: 2 warnings emitted
Finished dev [unoptimized + debuginfo] target(s) in 1m 12s
Running `target/debug/extergate --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

<pre>chen116@e22-15:~/rust/rustsys 65x16 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"</pre>	<pre>chen116@e22-16:~/rust/rustsys 65x16 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"</pre>
<pre>chen116@e22-15:~/rust/rustsys 61x16 Finished dev [unoptimized + debuginfo] target(s) in 8.02s Running `target/debug/extergate --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"</pre>	<pre>chen116@e22-16:~/rust/rustsys 61x16 ^^^^^^ 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/extergate --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"</pre>

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)

<pre> 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 </pre>	<pre> tx established 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 </pre>
<pre> 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" </pre>	<pre> = 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" </pre>

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)
