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Knight Foundation School of Computing and Information Sciences

Software Engineering Focus

Final Deliverable

Project Title:
HOMA

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Abstract

Nowadays people rely heavily on technology, everything is becoming digital including communication, study, work, etc.... And to better meet this massive demand, a reliable transport protocol is needed. For a long and illustrious time, TCP has been the most used transport protocol. However, it comes with major performance problems and limitations to the scalability of applications due to the inaccuracy of aspects of its virtual design. Therefore, the HOMA project was introduced to replace TCP. It is designed quite differently to meet the needs of large-scale datacenters applications.

This document presents the information necessary to gain a good understanding of HOMA new transport protocol for modern datacenters and its purpose. It provides the User Stories assigned and implemented along with project plan, system requirement, and system design.

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INTRODUCTION:

We will evaluate different potential contributions to ameliorate the HOMA project. The first section includes a description of the current system, explanation how it was implemented, its advantages, and what is missing. Followed by another section that describes the purpose of the new improvement

Current System:

HOMA is a novel transport protocol (like TCP, UDP, etc....) proposed recently in a paper by Montazeri et al that is specifically designed to dramatically improve the performance of message-passing in networks with a high-volume of small messages. Specifically, HOMA is an attempt to catch up to hardware latency capabilities by exploiting the fact that the vast majority of messages in most network applications is in the range of a few hundred bytes. By addressing this HOMA achieves a speedup of almost 100x in such situations.

HOMA relies on three main design principles to achieve its goals:

- **Priority Queues:** HOMA heavily exploits the priority queues present in modern-day network switches by assigning priorities in a highly efficient and dynamic manner.
- **Controlled Overcommitment:** HOMA overcommits receiver downlinks to make the most efficient use of bandwidth possible. This is crucial to reducing queuing, which is one of the main sources of HOMA speed, because it addresses one of the main difficulties that arises with the way HOMA schedules packets.
- **Connectionless Design:** One of HOMA's main sources of speed is its strong crackdown on queuing times via a dramatic reduction in message latency. A streaming approach (like in TCP) increases message latency, since it necessitates the establishment of a connection. Thus, in order to achieve minimum latency, it is necessary to transmit packages "blindly", i.e., in a connectionless way.

Even though there are plenty of explanations on how HOMA is implemented and why it is better than TCP. It is still new, and people will tend to trust TCP more due to the fact it was around for

so long. After a series of meeting with the product owner and all the team members, a need for detailed comparison between HOMA, TCP, and UDP was concluded.

Purpose of New System

To better explain the advantages of HOMA, we collected data and graphs generated by the Homa Protocol implemented with ns-3, modified the HOMA test code so as to be able to provide a specific file size for comparison purposes, developed a test bench timer to be implemented for HOMA to be able to equally measure both protocols, and created a working server-client TCP and UDP connection. Then we developed a website, where we posted the comparison between the Homa Protocol and a regular TCP or UDP protocol that we created using the data found in our studies.

USER STORIES

The following section provides the detailed user stories that were implemented in this iteration of the project. These user stories served as the basis for the implementation of the project's features. This section also shows the user stories that are to be considered for future development.

Implemented User Stories

- User Story Data Documentation: As a user, I would like to understand the data generated by the Homa Protocol implemented with ns-3.
- User Story Graphs Documentation: As a user, I would like to understand the graphs generated by the Homa Protocol implemented with ns-3..
- User Story HOMA File Size Modification: As a developer, I would like to modify the HOMA test code so as to be able to provide a specific file size for comparison purposes.
- User Story HOMA timer: As a developer, I would like to develop a test bench timer to be implemented for HOMA, to be able to equally measure both protocols.
- User Story TPC Protocol: As a developer, I would like to have a working server-client TCP connection to be able to use it for comparisons to the Homa protocol.
- User Story UDP Protocol: As a developer, I would like to have a working server-client UDP connection to be able to use it for comparisons to the HOMA protocol.
- User Story Back-end Website: As a developer I would like to use the data found in our studies to create a comparison between the Homa Protocol and a regular TCP protocol.
- User Story Front-end Website: As a developer, I would like to develop a front-end using WordPress to display our findings.
- User Story User-friendly Website: As a user, I would like the website to display the differences between Homa and TCP protocols in an easy-to-understand matter.
- User Story UI Redesign for Data Presentation: As a designer, I would like to provide a mockup and redesign the website with the intention of better presenting our test results.
- User Story Poster Design: As a user, I would like to have a visual presentation of how HOMA compares against TCP and UDP.

Pending User Stories

- User Story Interactive Website: As a user, I would like to have an interactive website where I can test the three protocols in real time for optimal representation.
- User Story Code Documentation: As a developer, I would like to have access to deep and descriptive documentation on the Homa protocol.

PROJECT PLAN

This section describes the planning that went into the realization of the HOMA project. This project incorporated the agile development techniques and as such required the sprints to be planned. These sprint plannings are detailed in the section. This section also describes the components, both software and hardware, chosen for this project.

Hardware and Software Resources

The following is a list of all hardware and software resources that were used in the HOMA project:

- Desktops/laptops
- GitHub
- Oracle VM VirtualBox
- JavaScript
- HTML
- CSS
- OneDrive
- Ubuntu
- Git
- MYSQL
- Linux

Sprints Plan

Sprint 1

Attendees: Fares Amamou, Maria Correa, Alexander Zablah, Nathan Nunez, Diego Castro Estrada

Date: 01/20/2023

Start time: 11:30 PM

End time: 12:00 PM

After discussion, the velocity of the team was estimated to be 3.

The product owner chose the following user stories to be done during the next sprint. They are ordered based on their priority.

- User Story 1 Connect: The user can connect to the HOMA protocol. (5 points)
- User Story 2 Disconnect: The user can disconnect from the HOMA protocol. (5 points)
- User Story 3 Receive Data: The user can receive data through the HOMA protocol. (5 points)
- User Story 4 Send Data: The user can send data through the HOMA protocol. (5 points)
- User Story 5 Delete Data: The user can delete data from the server using the HOMA protocol. (5 points)

Sprint 2

Attendees: Fares Amamou, Maria Correa, Alexander Zablah, Nathan Nunez, Diego Castro Estrada

Date: 01/30/2023

Start time: 6:45 PM

End time: 7 PM

After discussion, the velocity of the team was estimated to be 3.

The product owner chose the following user stories to be done during the next sprint. They are ordered based on their priority.

- User Story 1 Connect: As a user, I would like to connect to the HOMA protocol. (5 points)
- User Story 2 Disconnect: As a user, I would like to disconnect from the HOMA protocol. (5 points)
- User Story 3 Receive Data: As a user, I would like to receive data through the HOMA protocol. (5 points)
- User Story 4 Send Data: As a user, I would like to send data through the HOMA protocol. (5 points)
- User Story 5 Delete Data: As a user, I would like to delete data from the server using the HOMA protocol. (5 points)

Sprint 3

Attendees: Fares Amamou, Maria Correa, Alexander Zablah, Nathan Nunez, Diego Castro Estrada

Date: 02/13/2023

Start time: 6:45 PM

End time: 7:10 PM

After discussion, the velocity of the team was estimated to be 4.

The product owner chose the following user stories to be done during the next sprint. They are ordered based on their priority.

- User Story 1 Connect: As a user, I would like to connect to the HOMA protocol. (5 points)
- User Story 2 Disconnect: As a user, I would like to disconnect from the HOMA protocol. (5 points)
- User Story 3 Receive Data: As a user, I would like to receive data through the HOMA protocol. (5 points)
- User Story 4 Send Data: As a user, I would like to send data through the HOMA protocol. (5 points)
- User Story 5 Delete Data: As a user, I would like to delete data from the server using the HOMA protocol. (5 points)
- User Story 6 Search for Data: As a user, I would like to be able to search for certain data using the HOMA protocol. (5 points)
- User Story 7 Filter Data: As a user, I would like to be able to filter data using the HOMA protocol. (5 points)

Sprint 4

Attendees: Fares Amamou, Maria Correa, Alexander Zablah, Nathan Nunez

Date: 03/6/2023

Start time: 6:30 PM

End time: 7:00 PM

After discussion, the velocity of the team was estimated to be 4.

The product owner chose the following user stories to be done during the next sprint. They are ordered based on their priority.

- User Story 1 Data Documentation: As a user, I would like to understand the data generated by the Homa Protocol implemented with ns-3. (5 points)
- User Story 2 Graphs Documentation: As a user, I would like to understand the graphs generated by the Homa Protocol implemented with ns-3. (5 points)
- User Story 3 Front-end Website: As a developer, I would like to develop a front-end using WordPress to display our findings. (5 points)
- User Story 4 Back-end Website: As a developer I would like to use the data found in our studies to create a comparison between the Homa Protocol and a regular TCP protocol. (5 points)

- User Story 5 User-friendly Website: As a user, I would like the website to display the differences between Homa and TCP protocols in an easy-to-understand matter. (5 points)
- User Story 6 TPC Protocol: As a developer, I would like to have a working server-client TCP connection to be able to use it for comparisons to the Homa protocol. (5 points)
- User Story 7 Code Documentation: As a developer, I would like to have access to deep and descriptive documentation on the Homa protocol. (5 points)

Sprint 5

Attendees: Fares Amamou, Maria Correa, Alexander Zablah, Nathan Nunez

Date: 03/20/2023

Start time: 6:30 PM

End time: 7:00 PM

After discussion, the velocity of the team was estimated to be 4.

The product owner chose the following user stories to be done during the next sprint. They are ordered based on their priority.

- User Story 3 Front-end Website: As a developer, I would like to develop a front-end using WordPress to display our findings. (5 points)
- User Story 4 Back-end Website: As a developer I would like to use the data found in our studies to create a comparison between the Homa Protocol and a regular TCP protocol. (5 points)
- User Story 6 TCP Protocol: As a developer, I would like to have a working server-client TCP connection to be able to use it for comparisons to the Homa protocol. (5 points)
- User Story 8 UI Redesign for Data Presentation: As a designer, I would like to provide a mockup and redesign the website with the intention of better presenting our test results. (5 points)
- User Story 9 HOMA File Size Modification: As a developer, I would like to modify the HOMA test code so as to be able to provide a specific file size for comparison purposes. (5 points)
- User Story 10 HOMA timer: As a developer, I would like to develop a test bench timer to be implemented for HOMA, to be able to equally measure both protocols. (5 points)
- User Story 11 UDP Protocol: As a developer, I would like to have a working server-client UDP connection to be able to use it for comparisons to the HOMA protocol. (5 points)

- User Story 12 Poster Design: As a user, I would like to have a visual presentation of how HOMA compares against TCP and UDP.

Sprint 6

Attendees: Fares Amamou, Maria Correa, Alexander Zablah, Nathan Nunez

Date: 04/03/2023

Start time: 6:30 PM

End time: 7:00 PM

After discussion, the velocity of the team was estimated to be 4.

The product owner chose the following user stories to be done during the next sprint. They are ordered based on their priority.

- User Story 3 Front-end Website: As a developer, I would like to develop a front-end using WordPress to display our findings. (5 points)
- User Story 4 Back-end Website: As a developer I would like to use the data found in our studies to create a comparison between the Homa Protocol and a regular TCP protocol. (5 points)
- User Story 8 UI Redesign for Data Presentation: As a designer, I would like to provide a mockup and redesign the website with the intention of better presenting our test results. (5 points)
- User Story 11 UDP Protocol: As a developer, I would like to have a working server-client UDP connection to be able to use it for comparisons to the HOMA protocol. (5 points)
- User Story 12 Poster Design: As a user, I would like to have a visual presentation of how HOMA compares against TCP and UDP.
- User Story 13 Interactive Website: As a user, I would like to have an interactive website where I can test the three protocols in real time for optimal representation. (5 points).

Sprint 7

Attendees: Fares Amamou, Maria Correa, Alexander Zablah, Nathan Nunez

Date: 04/17/2023

Start time: 6:30 PM

End time: 7:00 PM

After discussion, the velocity of the team was estimated to be 4.

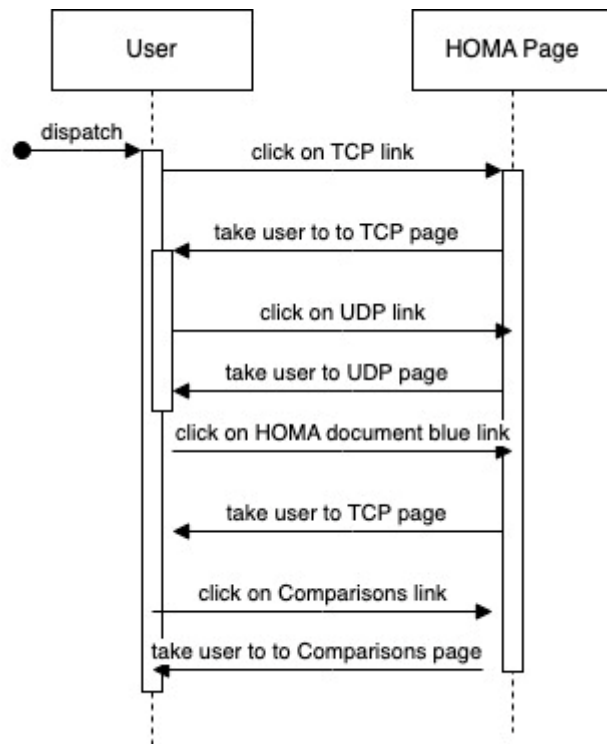
The product owner chose the following user stories to be done during the next sprint. They are ordered based on their priority.

- User Story 14 Individual Poster: As a developer, I need to design and write a poster describing what I personally worked on for the project. (5 points).
- User Story 15 PowerPoint Slides: As a developer, I need to create PowerPoint slides based on what I worked on for the project to present in the introductory video. (5 points).
- User Story 16 Introduction Video: As a developer, I need to film an introduction video to introduce the project. (5 points)
- User Story 17 Demo Video: As a developer, I need to film a demo video, demoing the finished product of the project. (5 points).
- User Story 18 Documentation: As a developer, I need to properly document the process of the project and its deliverables. (5 points).
- User Story 19 Presentation: As a developer, I need to properly prepare for the final presentation. (5 points).

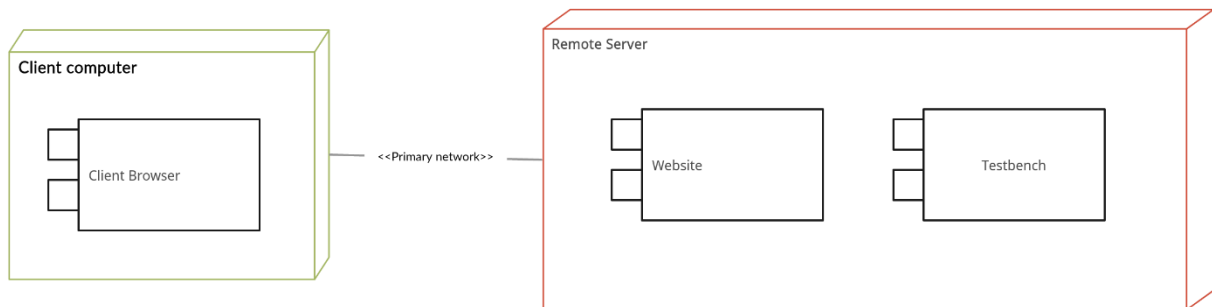
SYSTEM DESIGN

This section contains information on the design decisions that went into this project. The architecture patterns are outlined and explained. The entire system is shown in a package diagram and the subsystems are explained. Finally, the design patterns used in the project are discussed.

Sequence Diagram



Deployment Diagram



GLOSSARY

Agile Development: Agile development is an iterative software-development methodology which teams use in projects.

Algorithm: A process or set of rules to be followed in calculations or other problem-solving operations, especially by a computer.

Capstone: The completion marker, of a student's coursework leading to the culmination of their program with a degree in their chosen field of study.

Hardware: The machines, wiring, and other physical components of a computer or other electronic system.

Product Owner: Defines user stories and creates a product backlog.

Software: The programs and other operating information used by a computer. **Sprint:** A short, time-boxed period when a scrum team works to complete a set amount of work.

Unified Modeling Language (UML): A standard notation for the modeling of real-world objects as a first step in developing an object-oriented design methodology.

User Interface (UI): The means by which the user and a computer system interact, in particular the use of input devices and software.

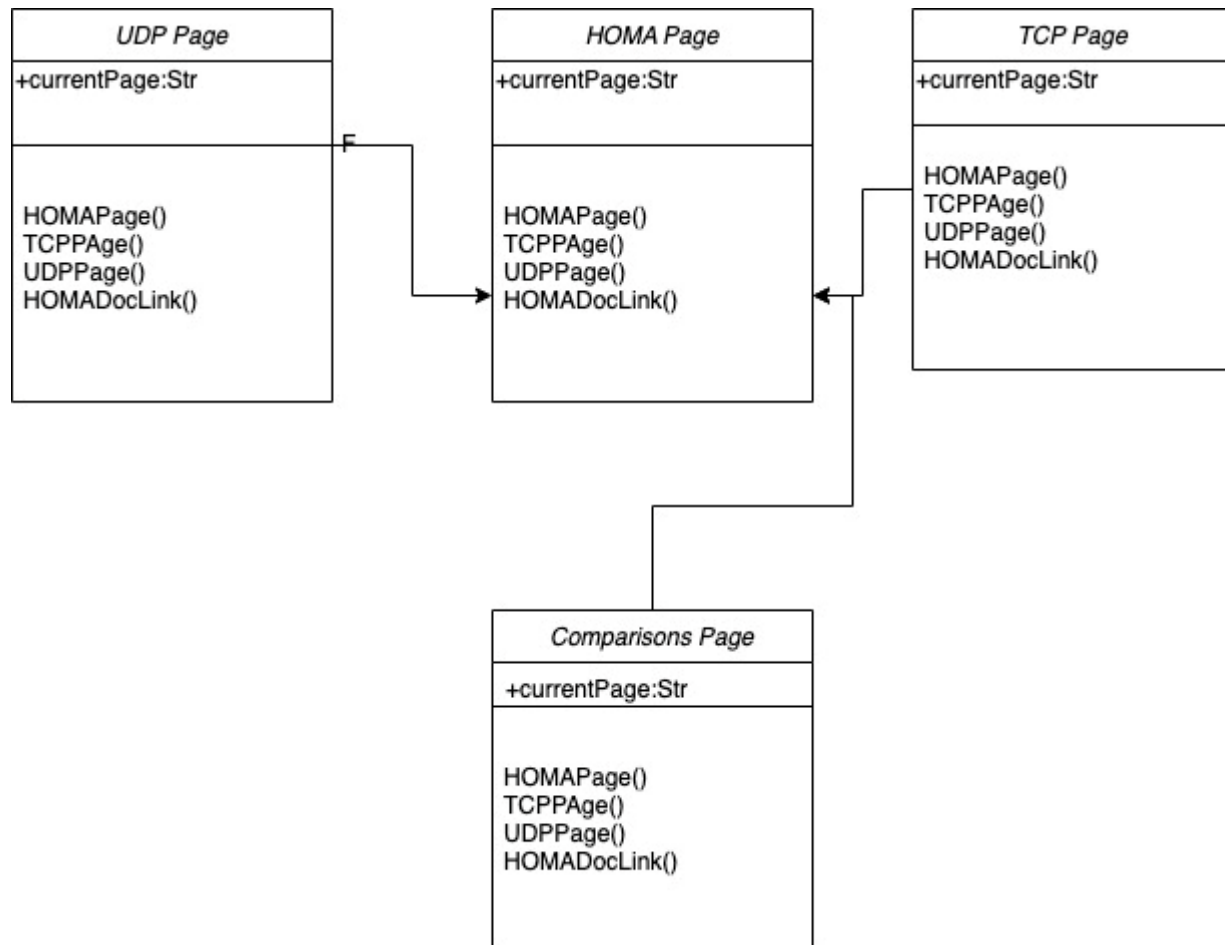
User Story: A user story is an informal, general explanation of a software feature written from the perspective of the end user or customer.

VM: Virtual Machine.

Linux: Operating system in which implementation of the project was done.

APPENDIX

Appendix A - UML Diagrams



Appendix B - User Interface Design



Appendix C - Sprint Review Reports

Sprint 1

Date: 01/29/2023

Attendees: Fares Amamou, Maria Correa, Alexander Zablah, Nathan Nunez, Diego Castro Estrada

Start time: 6pm

End time: 7pm

After a show and tell presentation, the implementation of the following user stories was accepted by the product owners:

04/16/2023

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- The PO still did not accept any user story for implementation as we are still in the process of research and collecting information about the HOMA

The following ones were rejected and moved back to the product backlog to be assigned to a future sprint at a future Sprint Planning meeting.

- Still did not decide

Sprint 2

Date: 02/12/2023

Attendees: Fares Amamou, Maria Correa, Alexander Zablah, Nathan Nunez, Diego Castro Estrada

Start time: 6pm

End time: 7pm

After a show and tell presentation, the implementation of the following user stories was accepted by the product owners:

- The PO ended up accepting our user stories after our first meeting.

The following ones were rejected and moved back to the product backlog to be assigned to a future sprint at a future Sprint Planning meeting.

- None so far

Sprint 3

Date: 02/26/2023

Attendees: Fares Amamou, Maria Correa, Alexander Zablah, Nathan Nunez, Diego Castro Estrada

Start time: 9pm

End time: 10pm

After a show and tell presentation, the implementation of the following user stories was accepted by the product owners:

- No implementation yet because of the issues with making a client and server in HOMA.

The following ones were rejected and moved back to the product backlog to be assigned to a future sprint at a future Sprint Planning meeting.

- None so far

Sprint 4

Date: 04/02/2023

Attendees: Fares Amamou, Maria Correa, Alexander Zablah, Nathan Nunez, Diego Castro Estrada

Start time: 10:30pm

End time: 11:30pm

After a show and tell presentation, the implementation of the following user stories was accepted by the product owners:

- The PO accepted our proposed user stories.

The following ones were rejected and moved back to the product backlog to be assigned to a future sprint at a future Sprint Planning meeting.

- None so far

Sprint 5

Date: 04/02/2023

Attendees: Fares Amamou, Maria Correa, Alexander Zablah, Nathan Nunez, Diego Castro Estrada

Start time: 10:30pm

End time: 11:30pm

After a show and tell presentation, the implementation of the following user stories was accepted by the product owners:

- The PO accepted our proposed user stories.

The following ones were rejected and moved back to the product backlog to be assigned to a future sprint at a future Sprint Planning meeting.

- None so far

Sprint 6

Date: 04/13/2023

Attendees: Fares Amamou, Maria Correa, Alexander Zablah, Nathan Nunez, Diego Castro Estrada

Start time: 9pm

End time: 10pm

After a show and tell presentation, the implementation of the following user stories was accepted by the product owners:

- User Story 3 Front-end Website: As a developer, I would like to develop a front-end using WordPress to display our findings. (5 points)
- User Story 4 Back-end Website: As a developer I would like to use the data found in our studies to create a comparison between the Homa Protocol and a regular TCP protocol. (5 points)
- User Story 8 UI Redesign for Data Presentation: As a designer, I would like to provide a mockup and redesign the website with the intention of better presenting our test results. (5 points)
- User Story 11 UDP Protocol: As a developer, I would like to have a working server-client UDP connection to be able to use it for comparisons to the HOMA protocol. (5 points)
- User Story 12 Poster Design: As a user, I would like to have a visual presentation of how HOMA compares against TCP and UDP. (5 points)

The following ones were rejected and moved back to the product backlog to be assigned to a future sprint at a future Sprint Planning meeting.

- User Story 13 Interactive Website: As a user, I would like to have an interactive website where I can test the three protocols in real time for optimal representation. (5 points)

Appendix D - User Manuals, Installation/Maintenance Document, Shortcomings/Wishlist Document, and other documents

Wenjia Update 2/28/2023

How to run this project:

1. build your own DIRECTORY in your own linux: "mkdir workplace4HOMA", then "cd workplace4HOMA" & git clone there.

(if you haven't build ur own linux, check this: <https://medium.com/tech-lounge/how-to-install-ubuntu-on-mac-using-virtualbox-3a26515aa869>)

1. git clone <https://github.com/HOMA-Repo/HOMA-project.git>
2. ./waf configure
3. ./waf

(you should be ablt to see this after building using (./waf):

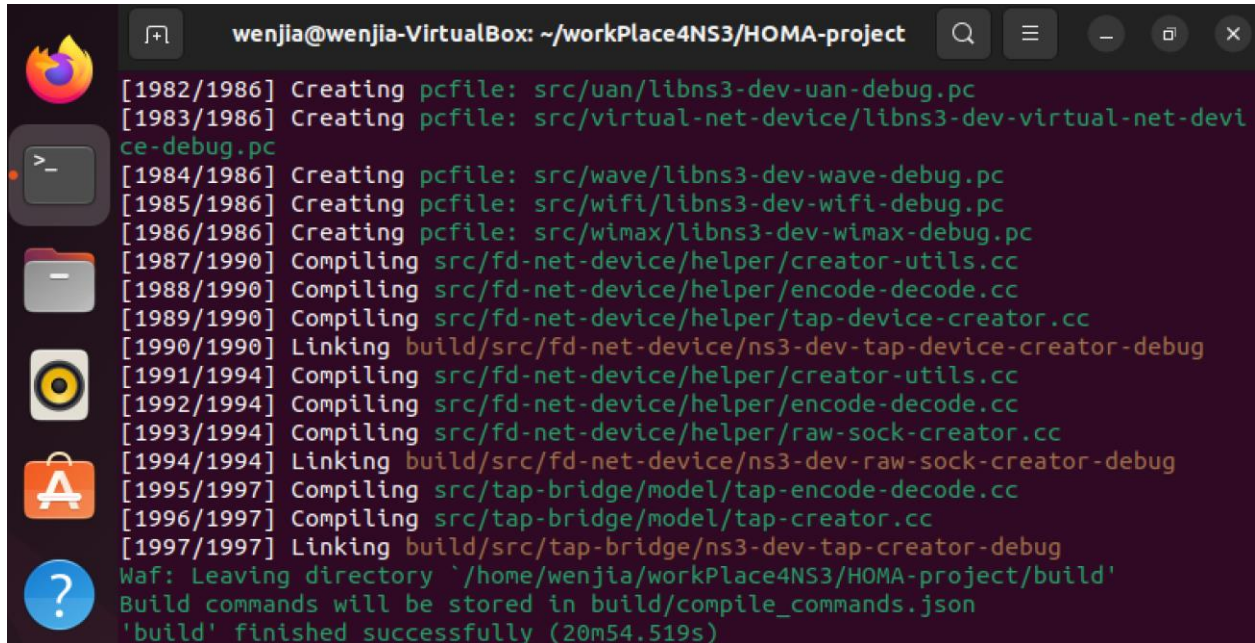
```
,-Bdynamic']
Waf: Leaving directory `/home/wenjia/workPlace4NS3/HOMA-project/build
Build commands will be stored in build/compile_commands.json
'build' finished successfully (21m0.646s)

Modules built:
antenna          aadv          applications
bridge           buildings     config-store
core             csma          csma-layout
dsdv             dsr           energy
fd-net-device    flow-monitor  internet
internet-apps    lr-wpan       lte
mesh             mobility      netanim
network          nix-vector-routing
point-to-point   point-to-point-layout
sixlowpan        spectrum      stats
tap-bridge       test (no Python)
traffic-control  uan           topology-read
wave            wifi          virtual-net-devi
wimax

Modules not built (see ns-3 tutorial for explanation):
brite           click         dpdk-net-device
mpi             openflow      visualizer

wenjia@wenjia-VirtualBox:~/workPlace4NS3/HOMA-project$
```

how to test HOMA protocol: ./waf --run scratch/HomaL4Protocol-simple-test



```
wenjia@wenjia-VirtualBox: ~/workPlace4NS3/HOMA-project
[1982/1986] Creating pcfile: src/uan/libns3-dev-uan-debug.pc
[1983/1986] Creating pcfile: src/virtual-net-device/libns3-dev-virtual-net-devi
ce-debug.pc
[1984/1986] Creating pcfile: src/wave/libns3-dev-wave-debug.pc
[1985/1986] Creating pcfile: src/wifi/libns3-dev-wifi-debug.pc
[1986/1986] Creating pcfile: src/wimax/libns3-dev-wimax-debug.pc
[1987/1990] Compiling src/fd-net-device/helper/creator-utils.cc
[1988/1990] Compiling src/fd-net-device/helper/encode-decode.cc
[1989/1990] Compiling src/fd-net-device/helper/tap-device-creator.cc
[1990/1990] Linking build/src/fd-net-device/ns3-dev-tap-device-creator-debug
[1991/1994] Compiling src/fd-net-device/helper/creator-utils.cc
[1992/1994] Compiling src/fd-net-device/helper/encode-decode.cc
[1993/1994] Compiling src/fd-net-device/helper/raw-sock-creator.cc
[1994/1994] Linking build/src/fd-net-device/ns3-dev-raw-sock-creator-debug
[1995/1997] Compiling src/tap-bridge/model/tap-encode-decode.cc
[1996/1997] Compiling src/tap-bridge/model/tap-creator.cc
[1997/1997] Linking build/src/tap-bridge/ns3-dev-tap-creator-debug
Waf: Leaving directory `/home/wenjia/workPlace4NS3/HOMA-project/build'
Build commands will be stored in build/compile_commands.json
'build' finished successfully (20m54.519s)
```

tips: use

./waf clean

if you met any errors, it should help fix it.

(the executions of these commands could be long. some of them took me more than 40 minutes, please keep your machine running during executing)

This project is a combination of ns-3 and HOMA protocol (applied HOMA on ns-3).

ns-3-dev source code: <https://gitlab.com/nsnam/ns-3-dev>

source code of this demo: <https://github.com/serhatarslan-hub/HomaL4Protocol-ns-3>

REFERENCES

- [1] Behnam Montazeri, Yilong Li, Mohammad Alizadeh, and John Ousterhout. 2018. Homa: a receiver-driven low-latency transport protocol using network priorities. In *Proceedings of the 2018 Conference of the ACM Special Interest Group on Data Communication (SIGCOMM '18)*. Association for Computing Machinery, New York, NY, USA, 221–235. DOI:<https://doi.org/10.1145/3230543.3230564>
- [2] Behnam Montazeri, Yilong Li, Mohammad Alizadeh, and John Ousterhout. Homa: A Receiver-Driven Low-Latency Transport Protocol Using Network Priorities. In *Proceedings of ACM SIGCOMM 2018 (SIGCOMM '18)*. ACM, New York, NY, USA, 15 pages. <https://doi.org/10.1145/3230543.3230564>