NVIDIA DOCA Secure Channel 实验报告

1. 实验概述

现代数据中心分为三大支柱，即CPU、GPU、DPU。其中CPU负责单线程地执行通用计算任务、GPU可以大规模并行执行计算任务、DPU专门设计来加速数据密集型计算。DPU的出现能够将基础设施任务从CPU上卸载，并加速其运行速度，同时起到隔离各个区域，保护用户数据安全的作用。

本实验基于 **NVIDIA DOCA SDK**，旨在探索并实现 **Host**（主机）与 **DPU**（数据处理单元）之间的安全通信通道。实验的核心目标是通过使用 **DOCA Comm Channel APIs** 构建一个安全通道，确保数据在主机与DPU之间的可靠传输。此外，我们还计划扩展基本功能，支持更加复杂的数据交换和计算任务。

具体实验目标包括：

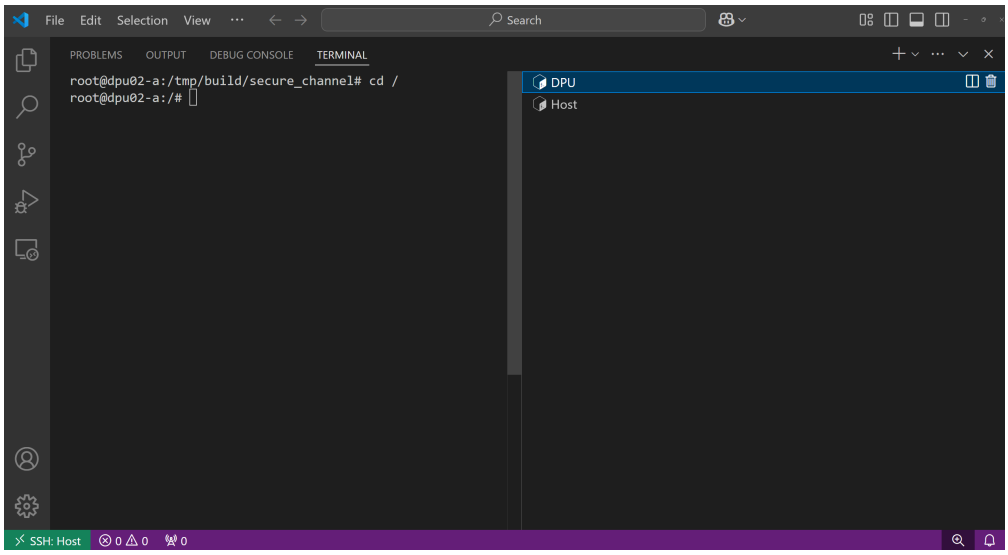
1. 理解并使用 **DOCA Comm Channel APIs** 创建安全通道，确保Host和DPU之间的高效和安全的数据通信。
2. 扩展功能一，通过 **JSON 配置文件** 来灵活配置通信参数，即使用json文件来导入configuration
3. 扩展功能二，为DPU开发简单的计算服务，支持host发送两个数字到dpu，并由dpu进行加法计算，输出结果到命令行

本报告将详细介绍实验的实施过程，包括实验环境搭建、基础功能实现、功能扩展、实验结果展示等内容，并总结实验成果与未来的改进方向。

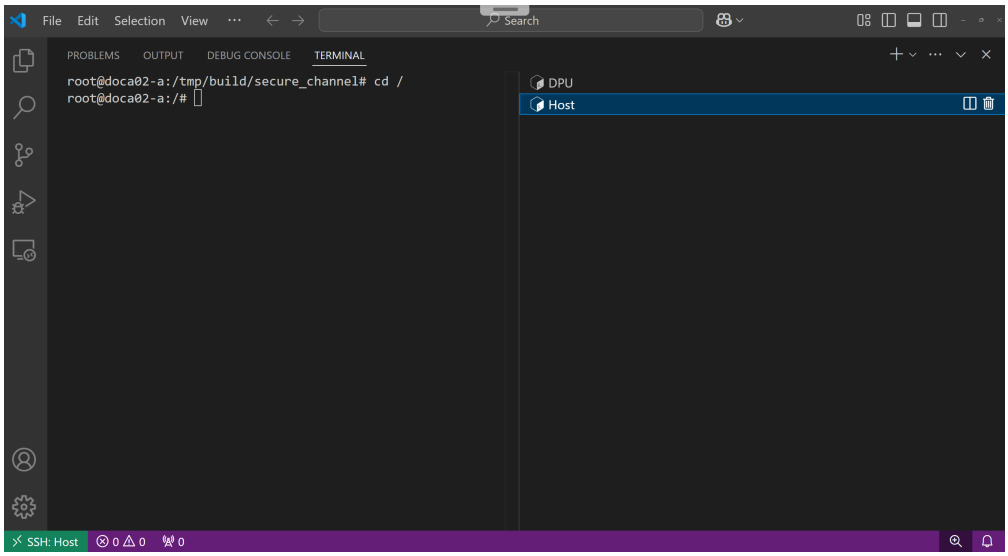
2. 实验环境搭建

2.1 连接机器

1. 下载atrust，按账号密码登录
2. 连接host： `ssh -p 22 doca@192.168.102.1` 密码： `@doca`
3. 在host中打开一个terminal连接dpu： `ssh -p 22 ubuntu@192.168.100.2` 密码： `@doca`



A terminal on Host connected to dpu



A terminal on Host

DOCA SDK 是NVIDIA为其数据处理单元（DPU）平台提供的一套开发工具包，旨在帮助开发者高效地开发、调试、部署基于DPU的加速应用。DOCA SDK包含多个功能模块，涵盖了从硬件加速到网络通信、数据处理、安全等各个方面。在本实验中，我们主要使用了 **DOCA Comm Channel**，它提供了创建和管理 Host 和 DPU 之间安全通信通道的能力。

2.2 编译准备

1. 切换到根目录

```
sudo -i
cd /
```

2. 编译

```
cd /opt/mellanox/doca/applications/
meson /tmp/build -Denable_all_applications=false -Denable_secure_channel=true
ninja -C /tmp/build
```

3. 在host和dpu都需要完成编译

3. 基础功能实现

3.1 运行应用程序

DOCA Comm Channel 是 DOCA SDK 中用于实现通信的模块，它支持 Host 和 DPU 之间的数据传输。在本实验中，我们利用 DOCA Comm Channel 创建了一个安全的通信通道，确保数据在主机与 DPU 之间能够可靠、安全地传输。通过该通道，主机可以向 DPU 发送消息，DPU 可以对消息进行处理，并将结果返回给主机。

1. 定位编译好的secure channel

```
cd /tmp/build/secure_channel/
./doca_secure_channel -h  # 查看帮助
```

2. DPU端运行

```
# 检查设备PCI地址
doca_caps --list-rep-devs
# Device PCI Address: 03:00.0
# Device Representor PCI Address: b1:00.0
./doca_secure_channel -s 256 -n 10 -p 03:00.0 -r b1:00.0
```

3. Host端运行

```
# 检查设备PCI地址
lspci | grep Mellanox
# Device PCI Address: 03:00.0
./doca_secure_channel -s 256 -n 10 -p 03:00.0
```

3.2 基础通信效果展示

```
root@dpu02-a:/tmp/build/secure_channel# ./doca_secure_channel -s 256 -n 10 -p 03:00.0 -r b1:00.0
[14:32:12:919682][2312519][DOCA][INF][secure_channel_core.c:495][init_cc] Started Listening, waiting for new connection
[14:32:12:919957][2312521][DOCA][INF][secure_channel_core.c:277][recvfrom_channel] Received message is:
[14:32:25:238393][2312521][DOCA][INF][secure_channel_core.c:277][recvfrom_channel] Received message is:
[14:32:25:238882][2312521][DOCA][INF][secure_channel_core.c:277][recvfrom_channel] Received message is: Hello from Host. This is: 0my message
[14:32:25:238912][2312521][DOCA][INF][secure_channel_core.c:277][recvfrom_channel] Received message is:
[14:32:25:238943][2312520][DOCA][INF][secure_channel_core.c:233][sendto_channel] Send thread exiting, total amount of messages sent successfully: 10
[14:32:25:238954][2312521][DOCA][INF][secure_channel_core.c:277][recvfrom_channel] Received message is: Hello from Host. This is: 1my message
[14:32:25:239038][2312521][DOCA][INF][secure_channel_core.c:277][recvfrom_channel] Received message is: Hello from Host. This is: 2my message
[14:32:25:239045][2312521][DOCA][INF][secure_channel_core.c:277][recvfrom_channel] Received message is: Hello from Host. This is: 3my message
[14:32:25:239052][2312521][DOCA][INF][secure_channel_core.c:277][recvfrom_channel] Received message is: Hello from Host. This is: 4my message
[14:32:25:239057][2312521][DOCA][INF][secure_channel_core.c:277][recvfrom_channel] Received message is: Hello from Host. This is: 5my message
[14:32:25:239060][2312521][DOCA][INF][secure_channel_core.c:277][recvfrom_channel] Received message is: Hello from Host. This is: 6my message
[14:32:25:239065][2312521][DOCA][INF][secure_channel_core.c:277][recvfrom_channel] Received message is: Hello from Host. This is: 7my message
[14:32:25:239068][2312521][DOCA][INF][secure_channel_core.c:277][recvfrom_channel] Received message is: Hello from Host. This is: 8my message
[14:32:25:239072][2312521][DOCA][INF][secure_channel_core.c:277][recvfrom_channel] Received message is: Hello from Host. This is: 9my message
[14:32:25:239077][2312521][DOCA][INF][secure_channel_core.c:277][recvfrom_channel] Received message is:
```

DPU received messages

```
root@doca02-a:/tmp/build/secure_channel# ./doca_secure_channel -s 256 -n 10 -p 03:00.0
[06:32:25:657611][302979][DOCA][INF][secure_channel_core.c:489][init_cc] Connection to DPU was established successfully
[06:32:25:658050][302980][DOCA][INF][secure_channel_core.c:198][sendto_channel] send message is: Hello from Host. This is: 0my message
[06:32:25:658112][302980][DOCA][INF][secure_channel_core.c:198][sendto_channel] send message is: Hello from Host. This is: 1my message
[06:32:25:658123][302980][DOCA][INF][secure_channel_core.c:198][sendto_channel] send message is: Hello from Host. This is: 2my message
[06:32:25:658131][302980][DOCA][INF][secure_channel_core.c:198][sendto_channel] send message is: Hello from Host. This is: 3my message
[06:32:25:658156][302980][DOCA][INF][secure_channel_core.c:198][sendto_channel] send message is: Hello from Host. This is: 4my message
[06:32:25:658173][302980][DOCA][INF][secure_channel_core.c:198][sendto_channel] send message is: Hello from Host. This is: 5my message
[06:32:25:658181][302980][DOCA][INF][secure_channel_core.c:198][sendto_channel] send message is: Hello from Host. This is: 6my message
[06:32:25:658189][302980][DOCA][INF][secure_channel_core.c:198][sendto_channel] send message is: Hello from Host. This is: 7my message
[06:32:25:658204][302980][DOCA][INF][secure_channel_core.c:198][sendto_channel] send message is: Hello from Host. This is: 8my message
[06:32:25:658215][302980][DOCA][INF][secure_channel_core.c:198][sendto_channel] send message is: Hello from Host. This is: 9my message
[06:32:25:658222][302980][DOCA][INF][secure_channel_core.c:242][sendto_channel] Send thread exiting, total amount of messages sent successfully: 10
```

Host sent messages

4. 功能扩展

4.1 JSON配置文件支持

在本实验中，我们通过 **DOCA Argp** 库实现了 JSON 配置文件的支持。**DOCA Argp** 是 DOCA SDK 中用于命令行参数解析的模块，它支持用户通过 JSON 文件灵活地配置应用程序的各种参数。在此基础上，我们为通信通道的设置提供了更为友好的配置方式，使得用户能够轻松调整传输参数（如消息大小、消息数量、PCI 地址等）。

4.1.1 实现原理

利用DOCA提供的 `doca_argp.h` 库实现JSON配置支持，主要包括：

1. `doca_argp_init`： 初始化argp模块
2. `register_secure_channel_params`： 注册参数
3. `doca_argp_start`： 解析命令行参数，支持JSON文件输入

4.1.2 使用演示

1. 创建JSON配置文件：

```
{
    "doca_general_flags": {
        "log-level": 60
    },
    "doca_program_flags": {
        "msg-size": 128,
        "num-msgs": 10,
        "pci-addr": "03:00.0",
        "rep-pci": "b1:00.0"
    }
}
```

2. DPU端运行效果：

```
root@dpu02-a:/tmp/build/secure_channel# ./doca_secure_channel --json sc_params.json
[12:54:17:920537][3341943][DOCA][INF][secure_channel_core.c:495][init_cc] Started Listening, waiting for new connection
[12:54:17:920762][3341945][DOCA][INF][secure_channel_core.c:277][recvfrom_channel] Received message is:
```

DPU server start by json file

3. Host端运行效果：

```
root@doca02-a:/tmp/build/secure_channel# ./doca_secure_channel --json  sc_params.json
[05:01:04:973587][311604][DOCA][INF][secure_channel_core.c:489][init_cc] Connection to DPU was established successfully
[05:01:04:974002][311605][DOCA][INF][secure_channel_core.c:198][sendto_channel] send message is: Hello from Host. This is: 0my
 message
[05:01:04:974070][311605][DOCA][INF][secure_channel_core.c:198][sendto_channel] send message is: Hello from Host. This is: 1my
 message
[05:01:04:974111][311605][DOCA][INF][secure_channel_core.c:198][sendto_channel] send message is: Hello from Host. This is: 2my
 message
[05:01:04:974120][311605][DOCA][INF][secure_channel_core.c:198][sendto_channel] send message is: Hello from Host. This is: 3my
 message
[05:01:04:974128][311605][DOCA][INF][secure_channel_core.c:198][sendto_channel] send message is: Hello from Host. This is: 4my
 message
[05:01:04:974136][311605][DOCA][INF][secure_channel_core.c:198][sendto_channel] send message is: Hello from Host. This is: 5my
 message
[05:01:04:974140][311605][DOCA][INF][secure_channel_core.c:198][sendto_channel] send message is: Hello from Host. This is: 6my
 message
[05:01:04:974145][311605][DOCA][INF][secure_channel_core.c:198][sendto_channel] send message is: Hello from Host. This is: 7my
 message
[05:01:04:974148][311605][DOCA][INF][secure_channel_core.c:198][sendto_channel] send message is: Hello from Host. This is: 8my
 message
[05:01:04:974151][311605][DOCA][INF][secure_channel_core.c:198][sendto_channel] send message is: Hello from Host. This is: 9my
 message
[05:01:04:974154][311605][DOCA][INF][secure_channel_core.c:242][sendto_channel] Send thread exiting, total amount of messages
sent successfully: 10
```

host send messages through json configuration

```
root@dpu02-a:/tmp/build/secure_channel# ./doca_secure_channel --json sc_params.json
[13:34:24:706375][3356748][DOCA][INF][secure_channel_core.c:495][init_cc] Started Listening, waiting for new connection
[13:34:24:706633][3356750][DOCA][INF][secure_channel_core.c:277][recvfrom_channel] Received message is:
[13:34:27:446372][3356750][DOCA][INF][secure_channel_core.c:277][recvfrom_channel] Received message is:
[13:34:27:446854][3356750][DOCA][INF][secure_channel_core.c:277][recvfrom_channel] Received message is: Hello from Host. This
is: 0my message
[13:34:27:446886][3356750][DOCA][INF][secure_channel_core.c:277][recvfrom_channel] Received message is: Hello from Host. This
is: 1my message
[13:34:27:446893][3356750][DOCA][INF][secure_channel_core.c:277][recvfrom_channel] Received message is: Hello from Host. This
is: 2my message
[13:34:27:446899][3356750][DOCA][INF][secure_channel_core.c:277][recvfrom_channel] Received message is: Hello from Host. This
is: 3my message
[13:34:27:446917][3356750][DOCA][INF][secure_channel_core.c:277][recvfrom_channel] Received message is: Hello from Host. This
is: 4my message
[13:34:27:446925][3356750][DOCA][INF][secure_channel_core.c:277][recvfrom_channel] Received message is: Hello from Host. This
is: 5my message
[13:34:27:446930][3356750][DOCA][INF][secure_channel_core.c:277][recvfrom_channel] Received message is: Hello from Host. This
is: 6my message
[13:34:27:446943][3356750][DOCA][INF][secure_channel_core.c:277][recvfrom_channel] Received message is: Hello from Host. This
is: 7my message
[13:34:27:446950][3356750][DOCA][INF][secure_channel_core.c:277][recvfrom_channel] Received message is: Hello from Host. This
is: 8my message
[13:34:27:446957][3356750][DOCA][INF][secure_channel_core.c:277][recvfrom_channel] Received message is: Hello from Host. This
is: 9my message
[13:34:27:446969][3356750][DOCA][INF][secure_channel_core.c:277][recvfrom_channel] Received message is:
[13:34:27:447066][3356749][DOCA][INF][secure_channel_core.c:233][sendto_channel] Send thread exiting, total amount of messages
 sent successfully: 256
```

dpu received messages

4.2 DPU加法计算服务

支持host发送两个数字到dpu，并由dpu进行加法计算，输出结果到命令行

4.2.1 实现方案

1. 扩展数据结构：在sc_config中添加a和b变量
2. 新增命令行参数： `--augend` 和 `--addend`
3. 修改数据传输逻辑，实现加法运算

4.2.2 功能演示

1. 查看新增参数：

```
doca@doca02-a:/tmp/build/secure_channel$ ./doca_secure_channel -h


Usage: doca_secure_channel [DOCA Flags] [Program Flags]

DOCA Flags:
  -h, --help                        Print a help synopsis
  -v, --version                     Print program version information
  -l, --log-level                   Set the (numeric) log level for the program <10=DISABLE, 20=CRITICAL, 30=ERROR, 40=WARNING, 50=IN
FO, 60=DEBUG, 70=TRACE>
  --sdk-log-level                   Set the SDK (numeric) log level for the program <10=DISABLE, 20=CRITICAL, 30=ERROR, 40=WARNING, 5
0=INFO, 60=DEBUG, 70=TRACE>
  -j, --json <path>                 Parse all command flags from an input json file

Program Flags:
  -s, --msg-size                    Message size to be sent
  -n, --num-msgs                    Number of messages to be sent
  -p, --pci-addr                    DOCA Comm Channel device PCI address
  -r, --rep-pci                     DOCA Comm Channel device representor PCI address (needed only on DPU)
  -a, --augend                      the first number that will be send to DPU
  -b, --addend                      the second number that will be send to DPU
```

show exist flags

2. 运行测试：

- 测试用例1：a=1, b=10

```
doca@doca02-a:/tmp/build/secure_channel$ ./doca_secure_channel -s 128 -n 1 -p "03:00.0" -r "b1:00.0" -a 1 -b 10
[15:41:15:186156][332332][DOCA][INF][secure_channel_core.c:541][init_cc] Connection to DPU was established successfully
[15:41:15:186431][332333][DOCA][INF][secure_channel_core.c:243][sendto_channel] send message is: 1,10
[15:41:15:186473][332334][DOCA][INF][secure_channel_core.c:321][recvfrom_channel] Received message is:
[15:41:15:186480][332333][DOCA][INF][secure_channel_core.c:287][sendto_channel] Send thread exiting, total amount of messages sent su
ccessfully: 1
```

host send a=1, b=10

```
ubuntu@dpu02-a:/tmp/build/secure_channel$ ./doca_secure_channel --json sc_params-new.json
[23:14:37:934286][4104617][DOCA][INF][secure_channel_core.c:553][init_cc] Started Listening, waiting for new connection
[23:14:37:934539][4104619][DOCA][INF][secure_channel_core.c:321][recvfrom_channel] Received message is:
[23:14:41:373487][4104619][DOCA][INF][secure_channel_core.c:321][recvfrom_channel] Received message is:
[23:14:41:373997][4104619][DOCA][INF][secure_channel_core.c:321][recvfrom_channel] Received message is:
[23:14:41:374037][4104619][DOCA][INF][secure_channel_core.c:321][recvfrom_channel] Received message is: 1,10
[23:14:41:374045][4104619][DOCA][INF][secure_channel_core.c:324][recvfrom_channel] after calculate, we can get the answer is: 11
```

dpu received a=1, b=10, and get a+b=11

- 测试用例2：a=1, b=20

```
doca@doca02-a:/tmp/build/secure_channel$ ./doca_secure_channel -s 128 -n 1 -p "03:00.0" -r "b1:00.0" -a 1 -b 20
[15:41:56:037754][332409][DOCA][INF][secure_channel_core.c:541][init_cc] Connection to DPU was established successfully
[15:41:56:038166][332410][DOCA][INF][secure_channel_core.c:243][sendto_channel] send message is: 1,20
[15:41:56:038220][332410][DOCA][INF][secure_channel_core.c:287][sendto_channel] Send thread exiting, total amount of messages sent su
ccessfully: 1
```

host send a=1, b=20

```
[23:42:41:034927][4114735][DOCA][INF][secure_channel_core.c:321][recvfrom_channel] Received message is:
[23:42:41:035388][4114735][DOCA][INF][secure_channel_core.c:321][recvfrom_channel] Received message is:
[23:42:41:035407][4114735][DOCA][INF][secure_channel_core.c:321][recvfrom_channel] Received message is: 20,20
[23:42:41:035414][4114735][DOCA][INF][secure_channel_core.c:324][recvfrom_channel] after calculate, we can get the answer is: 40
```

dpu received a=1, b=20, and get a+b=21

- 测试用例3：a=20, b=20

```
[23:41:55:725296][4114735][DOCA][INF][secure_channel_core.c:321][recvfrom_channel] Received message is:
[23:41:55:725828][4114735][DOCA][INF][secure_channel_core.c:321][recvfrom_channel] Received message is:
[23:41:55:725841][4114735][DOCA][INF][secure_channel_core.c:321][recvfrom_channel] Received message is: 1,20
[23:41:55:725848][4114735][DOCA][INF][secure_channel_core.c:324][recvfrom_channel] after calculate, we can get the answer is: 21
```

host send a=20, b=20

```
doca@doca02-a:/tmp/build/secure_channel$ ./doca_secure_channel -s 128 -n 1 -p "03:00.0" -r "b1:00.0" -a 20 -b 20
[15:42:41:362577][332461][DOCA][INF][secure_channel_core.c:541][init_cc] Connection to DPU was established successfully
[15:42:41:362898][332462][DOCA][INF][secure_channel_core.c:243][sendto_channel] send message is: 20,20
[15:42:41:362949][332462][DOCA][INF][secure_channel_core.c:287][sendto_channel] Send thread exiting, total amount of messages sent successfully: 1
```

dpu received a=20, b=20, and get a+b=40

5. 总结与展望

5.1 实验成果

1. 成功运行基本功能，基于DOCA SDK的安全通道通信
2. 完成JSON配置支持和DPU加法计算服务两个功能扩展
3. 体验DOCA框架在Host-DPU通信中的实用性

5.2 改进方向

1. 支持更复杂的数据结构传输
2. 增强错误处理机制
3. 优化性能和资源使用
4. 扩展更多计算功能

Appendix

分工情况：

- 李鹏宇：负责实现基础功能，并完成对应部分的程序文档（`README.md` 的 基础功能实现 部分）
- 李沐遥：负责实现拓展功能一和拓展功能二，并完成对应部分的程序文档（`README.md` 的 功能一 和 功能二 两部分）
- 刘明灏：探索其他direction的实现方法，并辅助实现目标功能，撰写实验报告
- 李伟涛：探索其他direction的实现方法，并辅助实现目标功能，撰写实验报告