INDIAN INSTITUTE OF TECHNOLOGY KHARAGPUR

Live Modifiable Server

by

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A thesis submitted in partial fulfilment for the
degree of Bachelor of Technology in
Computer Science and Engineering

Under the guidance of

Professor Sandip Chakraborty

Department of Computer Science and Engineering

Spring Semester, 2019-2020

DECLARATION

I, Himanshu Mundhra, certify that this thesis titled "**Live Modifiable Server**" and the work presented in it are my own. I also confirm that

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CERTIFICATE

This is to certify that the project report entitled "**Live Modifiable Server**" submitted by **Himanshu Mundhra** (Roll No. 16CS10057) to Indian Institute of Technology Kharagpur towards partial fulfilment of requirements for the award of degree of Bachelor of Technology (Hons.) in Computer Science and Engineering is a record of bona fide work carried out by him under my supervision and guidance during Spring Semester, 2019-2020.

June 11, 2020
Kharagpur

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INDIAN INSTITUTE OF TECHNOLOGY KHARAGPUR

Abstract

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Live Modifiable Server

by Himanshu Mundhra

We have build a robust system from scratch on C++ which envisions to add scalability and dynamism to existing Server-Client Connection Systems. We build over here, a concurrent server with a thread-per-connection concurrency-control mechanism. The Control Channel listens and accepts new connections, which are each then handled by a forked child called the Connection Channel. As the Connection Channel handles the connection, the Control Channel continues to accept connections and delegate them to forked Connection Channels.

Within the Connection Channel, a Data Channel is spawned using an execvp() and acts as an instance of data transfer between the Server and the Client. We develop an elaborate internal and external communication protocol which enables us to pause every connection (thereby terminating this instance), modify the executable of the Data Channel, and then re-spawn every instance of the Data Channel with the modified image - which resumes the connection from the previously paused state.

Acknowledgements

There are many people who I would like to thank as I pen down (or rather type out) my thesis. As my final semester started, I had plenty of plans both academic-research oriented as well as recreational. Things seemed all set for a grand end to a well rounded college life. But Alas! these unprecedented circumstances. I guess it are these life-threatening overtly challenging situations which give us some perspective and a realisation to truly acknowledge the valuable contributions which make our life easy.

I would like to thank my family for continuing to provide for me in these testing times and allow me to have the head space to actually be able to build this system from absolute scratch, and debug it right down to unaccounted bytes.

I would like to thank my friends for providing me with constant mental support allowing me to plough through my problems and find solutions on my own.

I would especially like to acknowledge the relief workers who worked continuously to revert the wreckage which the Super Cyclone Amphan caused to Kolkata, and my neighbourhood in particular. I would like to thank the Dean(UG) for his kind consideration to allow me some more time to complete my BTP-II in light of the disruption caused due to Amphan. Special thanks to my HOD - Prof. Dipanwita Roychoudhury, my FacAd - Prof. Sourangshu Bhattacharya and my panelists - Prof. Sudeshna Sarkar and Prof. Partha Bhowmick for understanding the gravity of my situation.

And last but not the least my guide and advisor Prof. Sandip Chakraborty for his unwaivering belief in my abilities, his valuable pointers to set me on course and in general being the kind and helpful person that he is.

I definitely could not reach the goals I had set at the start of the semester, but I am proud that I could build an end-to-end fully functional scalable system.

Contents

Chapter 1

The Different Actors

Description

There are various actors and entities involved in the functioning of the Live Modifiable Server System, each of which have their own indispensable roles to perform. We describe each of these actors in this Chapter.

1.1 Control Channel

The Control Channel acts as the backbone of the System. It is this process to which all the clients (BACKUP_Nodes or GET/PUT Clients) connect to.

Backup Nodes It initially accepts connections from all the Backup Nodes, registers them locally and sends out Confirmation INFO Packets to the Nodes. It continues to listen to Backup Nodes until a Timeout occurs or the Admin signals it an EOF with regards to incoming connections.

```
while (No System-Timeout && No Admin-EOF) {
    Accept_Connections(BACKUP_Node)
    Register(BACKUP_Node)
    Send_Confirmation(BACKUP_Node)
}
```

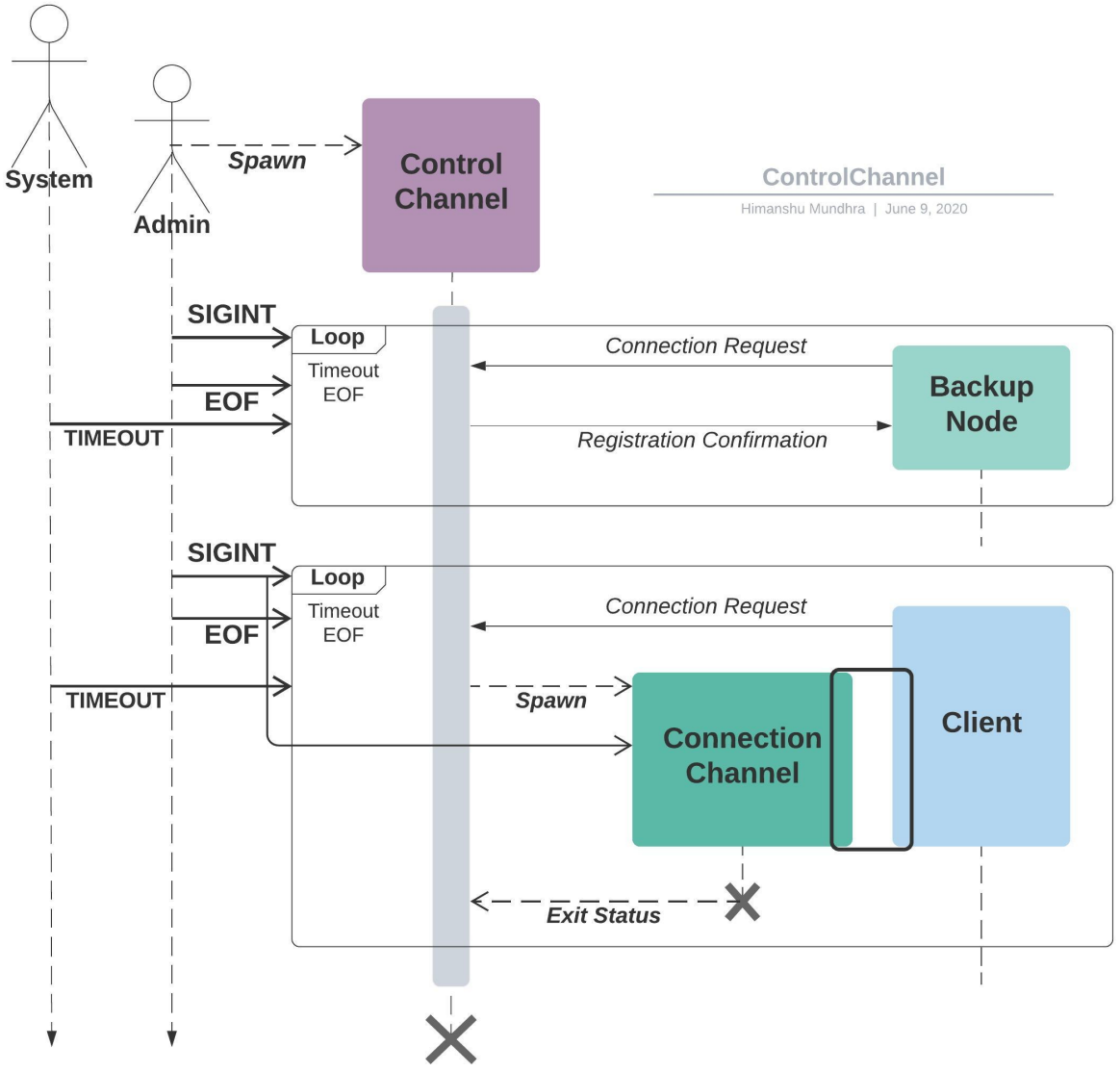

FIGURE 1.1: Sequence Diagram of Interactions at Control Channel

Data Clients It then listens and accepts connection from different GET and PUT Clients, forks a Connection Channel and delegates the responsibility of dealing with the Client to that particular Channel. This way the Control Channel is free to accept more connections. This is akin to the one-thread-per-connection concurrency control mechanism.

```
while (No System-Timeout && No Admin-EOF) {
    Accept_Connections(Data_Client)
    Fork(Connection_Channel)
    Delegate(Connection_Channel, Data_Client)
}
```

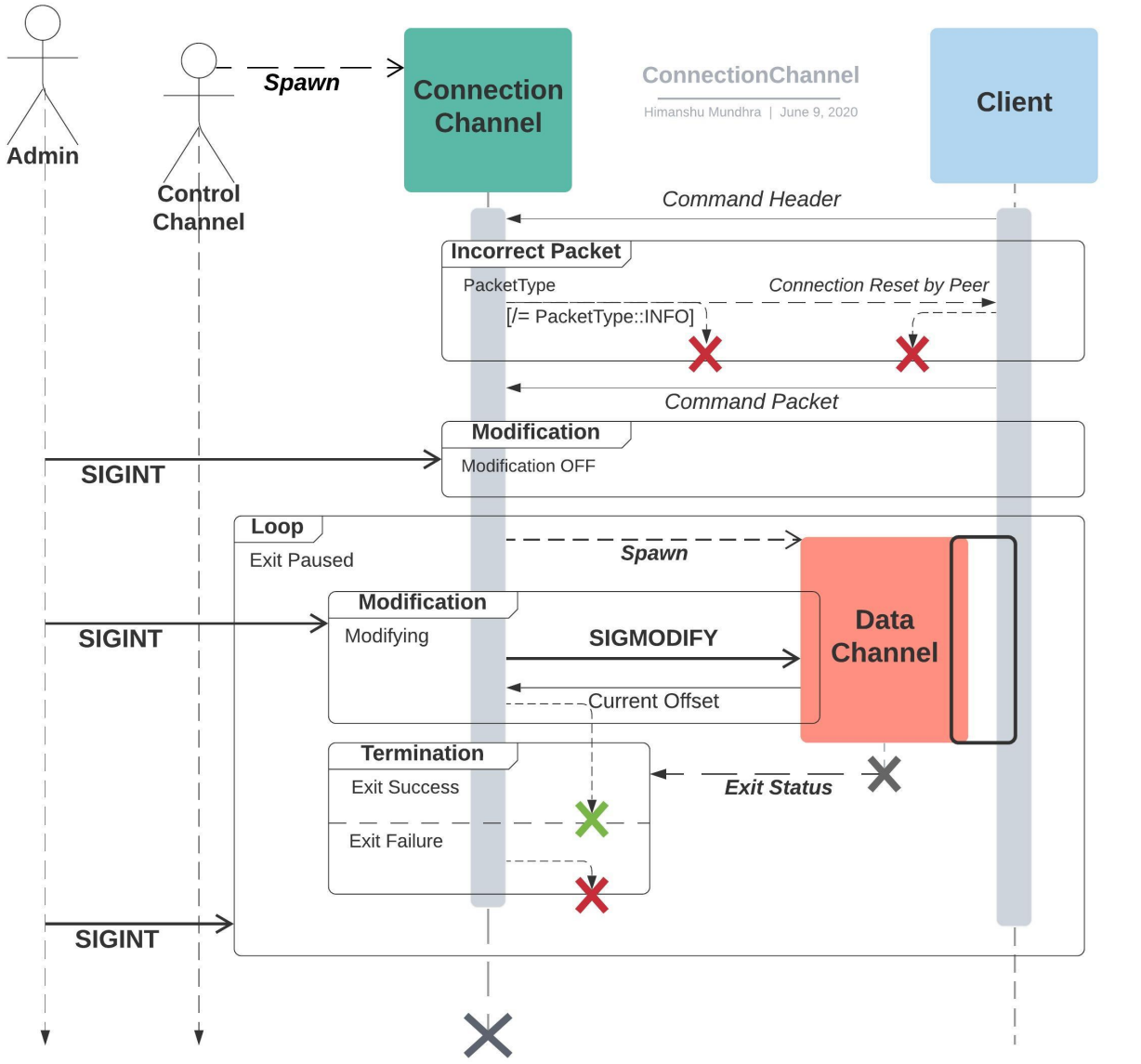

FIGURE 1.2: Sequence Diagram of Interactions at Connection Channel

1.2 Connection Channel

The Connection Channel acts as the henchman of the Control Channel, it is assigned a responsibility and it ensures that the task is brought to fruition. It takes care that the data transfer between the Server and the Client terminates - it might be a successful or failed data transfer.

Since the Connection Channel is forked by the Control Channel, it has the copy(-on-write()) of the complete address space of its parent. However there is no scope to modify the source code and come up with a new executable which can get reflected in the ongoing proceedings.

This is where the **Data Channel** comes into the picture. The Data Channel is a process spawned [*execvp()*] from the Connection Channel with it's own executable and address space.

It can be thought of as an **Instance of Data Transfer** between the Server and the Client - which goes on until the Transfer terminates or a Signal for a Modification is received.

It is this instance which is open for modification. The source code of the data channel can be modified and it's updated image can be pushed onto the ongoing proceedings - thereby providing our system with much needed dynamism.

```
recv(Command from Client)
do {
    if (ServerModifying) pauseFor(SIGINT)
    Spawn(Data_Channel)
    pauseFor(SIGINT, SIGCHLD)
    if (ServerModifying) {
        sendSignal(SIGMODIFY) -> Data_Channel
        recv(Updated_Offset) <- Data_Channel
    }
    ExitStatus = wait()
}
while (ExitStatus == PAUSED)
```

SIGINT (Ctrl+C or ^C) is an Interrupt which can be generated from the Terminal. The Admin uses the SIGINT Signal to alert the System of the start of the Server Modification Process. The SIGINT is to be sent to the whole process group (and not just the Control Channel) thereby alerting all the Connection Channels simultaneously.

```
SIGINT_SignalHandler() {
   ServerModifying = !ServerModifying
}
```

When the Connection Channel receives a SIGINT whilst a Data Channel is in progress, it sends a **SIGMODIFY** Signal to the Data Channel to terminate the transfer with a PAUSED Status. The Data Channel then returns an **offset** - which is the marker of percentage of data transfer completion. The Connection Channel then loops back and spawns a new Data Channel with this received offset.

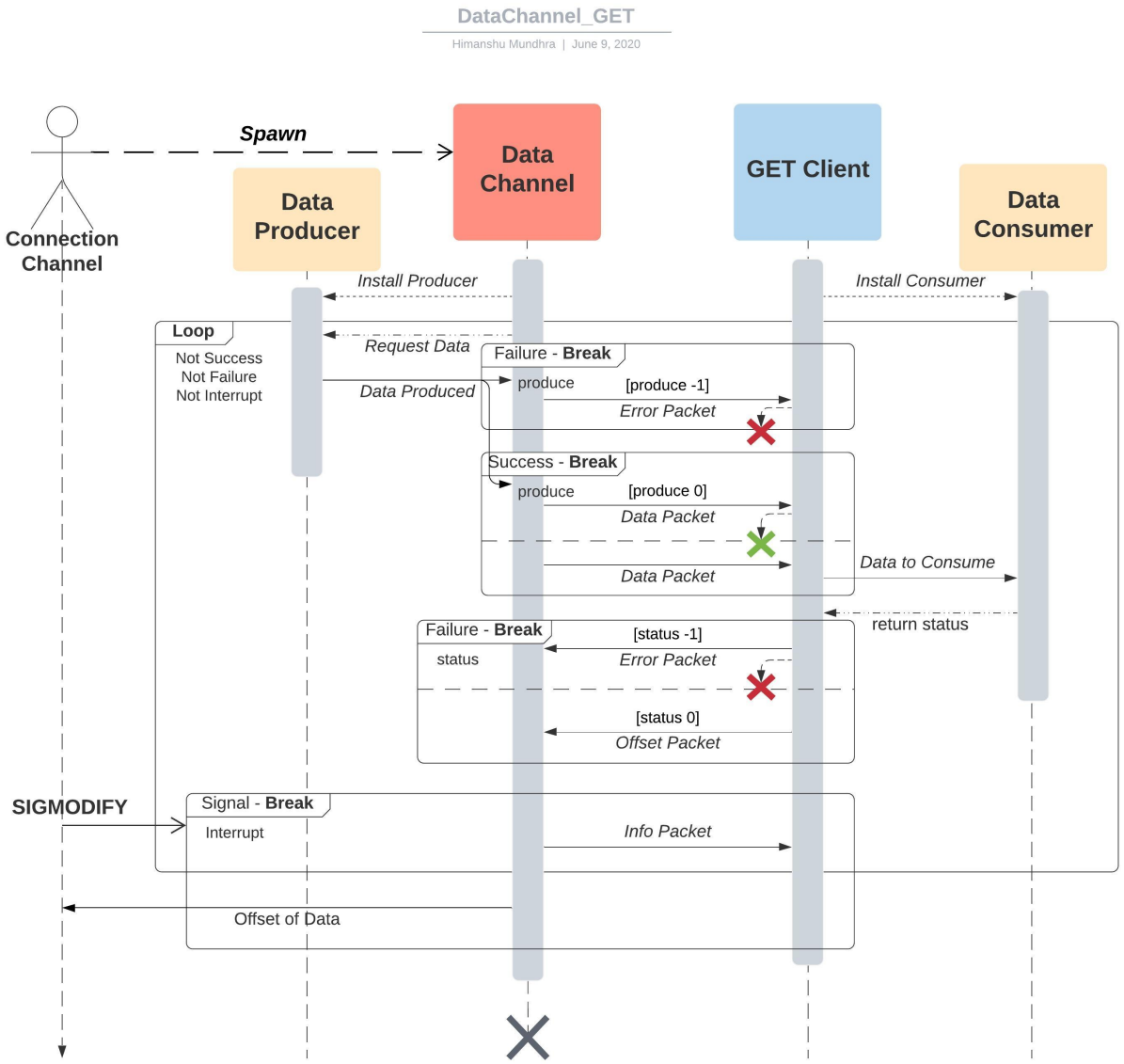

FIGURE 1.3: Sequence Diagram of Interaction between Data Channel and GET Clients

1.3 Data Channel and GET Clients

When connected to a **GET Client**, the Data Channel's task is to facilitate data transfer from the Server to the Client.

The Data Channel first installs the data producer on its side and starts requesting data from the offset provided by the connection channel (which is subsequently updated within the process itself).

It then sends the produced data to the GET Client, which then consumes the data as determined by it's needs as a Consumer. The Client then sends an Offset Packet which is basically a request to produce and send data from that offset. The offset at the Data Channel is thus updated.

GET Client It terminates successfully when data transfer is complete; and with an Error when the Server Side terminates the connection abruptly or the Consumer fails.

```
Consumer = Install()
while (No ServerError && No ConsumeError && Not Complete) {
    recv(Data) <= Data_Channel
    Consumption = Consumer.consume(data=Data)
    send(NewOffset) => Data_Channel
}
```

Data Channel This to-and-fro of data continues till the data transfer is complete. However, it may terminate prematurely due to Errors in Production or Sending, or on a SIGMODIFY.

```
Producer = Install()
while (No Error && Not Complete && No Interrupt) {
    Data = Producer.produce(offset=Offset)
    send(Data) => Client
    recv(Offset) <= Client
}
```

Interrupt at Data Channel The SIGMODIFY which the Data Channel receives from its parent - the Connection Channel associated with that Client basically sets a flag to terminate the ongoing data transfer with a PAUSED Status and return with the marked offset.

```
SIGMODIFY_SignalHandler() {
   Interrupt = 1
}
...
...
if (Interrupt) {
    send(Info) => Client
    send(Offset) => Connection_Channel
}
```

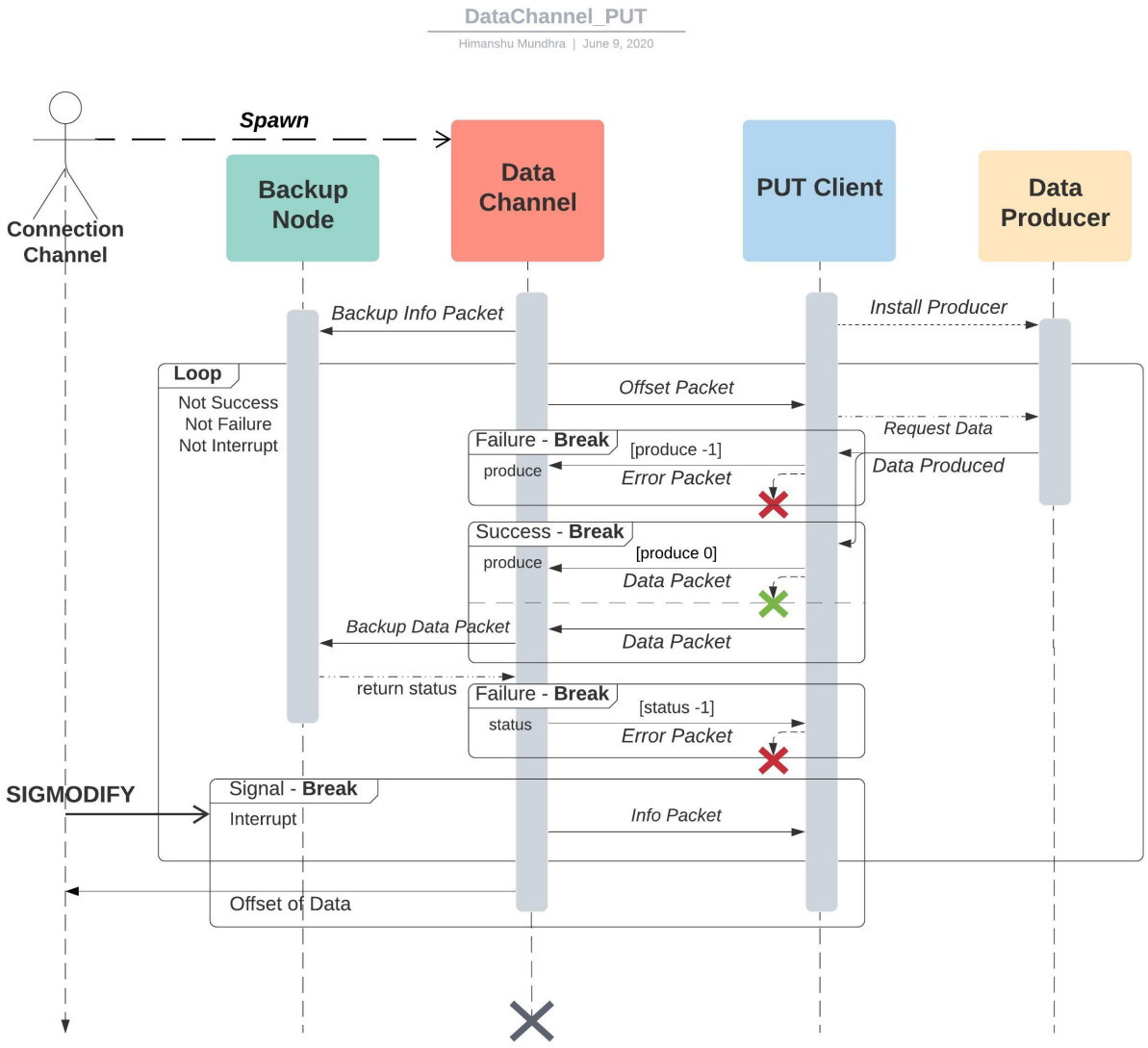

FIGURE 1.4: Sequence Diagram of Interaction between Data Channel and PUT Clients

1.4 Data Channel and PUT Clients

When connected to a **PUT Client**, the Data Channel's task is to facilitate data transfer from the Client to the Server to the BACKUP Node (if installed).

The Data Channel first sends a INFO Packet to the BACKUP Node in-use to inform it about the details of the data whose backup is going to be created.

It then initiates the transfer by requesting data from the client by sending an Offset Packet with the offset provided by the Connection Channel initially and updated subsequently.

The PUT Client, requests data from the producer by passing the required offset, and then forwards that data to the Server.

The Data Channel of the Server than forwards the Data Packet with some extra payload as a BackupData Packet to the BACKUP Node in-use. The offset is then updated as suitable.

Data Channel The termination of the Channel on Errors and Completion, and handling of the SIGMODIFY Interrupt remains the same.

```
send(BackupInfo) => BACKUP Node
while (No Error && Not Complete && No Interrupt) {
    send(Offset) => Client
    recv(Data) <= Client
    send(BackupData) => BACKUP Node
}
```

PUT Client It terminates successfully when data transfer is complete, and with an Error when Server Side terminates the connection abruptly or the Producer Fails.

```
Producer = Install()
while (No ServerError && No ProducerError && Not Complete) {
    recv(Offset) <= Data_Channel
    Data = Producer.produce(offset=Offset)
    send(Data) => Data_Channel
}
```

BACKUP Node It remains open to receive Backup Packets across Connection Channels. After receiving the Details in the BackupInfo Packet it registers the Connection Channel and appropriately stores the future BackupData Packets mapping them to the correct store using the Connection Channel PIDs.

```
do {
    recv(Backup Packet) <= Data Channel of any Connection Channel
    if (BackupInfo Received) Register Details of Expected BackupData
    if (BackupData Received) Store BackupData Appropriately
}
```

1.5 Producers and Consumers

These are entities which are installed externally at the Server and Client side during the data transfer part of our protocol.

Producers are installed at an host at the start of data transfer; they are invoked periodically to produce a chunk of data from the provided offset.

Consumers too are installed at the host in the beginning; they are invoked periodically to consume the chunk of data provided and return a marker of successful consumption.

An issue however which we might have overlooked here is the rewindibility of producers and consumers, and their mutual compatibility. **But what is Rewindibilty ??**

Rewindable Producers are a class of producers that have a notion of states and who can change their state on demand. In simpler words, a rewindable producer can *seek forward or backward* and start production of data from any point. This increases the complexity of the underlying implementation but on a less-reliable channel, the ability to produce data from the past in invaluable.

A **simple file** on a file system can be said to be a **Rewindable Producer** because we can use the *lseek()* function to seek to any point in the file, and then read data from there.

A **livestream of bytes** however, is a **Non-Rewindable Producer** since we can mostly not roll backward and produce past data again, and we most certainly cannot roll forward and produce data from the future.

Rewindable Consumers are the class of consumers which can request data from any offset - be it in the past or in the future. These consumers however need to have the provision of reverting back the changes in case they are going to re-consume some data, or in general be impervious to data re-consumption.

Compatability Not all producer-consumer pairs can be compatible with each other. For instance a Non-rewindable producer and a Rewindable Consumer are going to be incompatible. A Rewindable Consumer might request for an offset which is not corresponding to the current seek of the Producer, and being Non-Rewindable it cannot cater to that request.

Chapter 2

The Different Packets

Description

There are many different packets which do the rounds and are involved in the functioning of the Live Modifiable Server System, each of which have their own importance to the protocol followed by the system.

2.1 Error Packet

The Error Packet comes into use when an unexpected event abnormal to the correct control flow occurs - Socket Failed to Bind, Incorrect Filename, Data Production Failed, Incorrect Command Format and many others. As visible from the Sequence Diagrams above, after an Error Packet is sent or received, the Client crashes as Failed and the Server Side Channels terminate with a Failed Status.

Here is a description of what the different fields hold and mean -

Type - It holds the PacketType::ERROR which distinguishes it from other packets and intimates the receiver of which packet it is receiving.

Length - It holds an Integer Value which is the actual size of the Error Message which the sender has sent.

Error Message - Holds the string describing the error which occurred at the sender side.

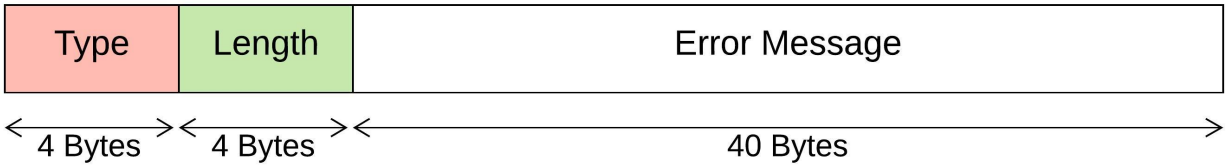

FIGURE 2.1: Error Packet

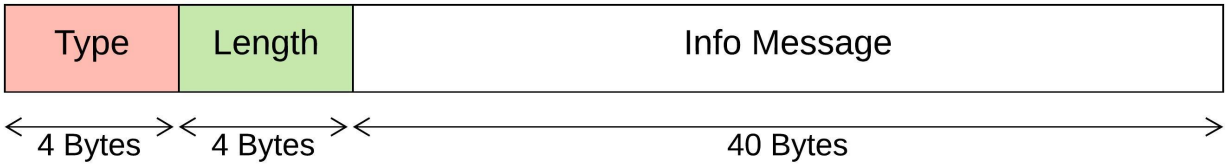

FIGURE 2.2: Info Packet

2.2 Info Packet

The Info Packet is a Multipurpose Packet which performs different tasks at different places in the System.

BACKUP Node connects to the Server, an Info Packet is sent to the Node to confirm its Registration.

Data Client connects to the Server, it sends an Info Packet which holds the Command to be performed in the Info Message field: **GET [Filename]** or **PUT [Filename]**.

Modification at Server side is taking place, the Data Channel sends an Info Packet to the Client to inform it about the delay in data transfer due to Code Modification taking place.

Here is a description of what the different fields hold and mean :

Type - It holds the PacketType::INFO which distinguishes it from other packets and intimates the receiver of which packet it is receiving.

Length - It holds an Integer Value which is the actual size of the Info Message which the sender has sent.

Info Message - Depends on the context of sending the Info Packet, as described above.

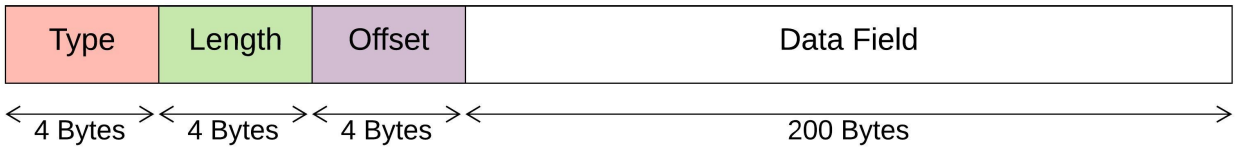

FIGURE 2.3: Data Packet

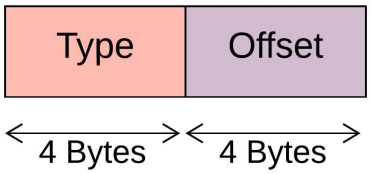

FIGURE 2.4: Offset Packet

2.3 Data and Offset Packets

Data Packet is the packet which contains the data being transferred from the Server to the Client (GET) and a Client to the Server (PUT).

Here is a description of what the different fields hold and mean :

Type - It holds the PacketType::DATA which distinguishes it from other packets and intimates the receiver of which packet it is receiving.

Length - It holds an Integer Value which is the actual size of the Data the sender has sent.

Offset - It holds an Integer Value which is the offset from which the Data has been produced.

Data Field - Holds the actual produced data.

Offset Packet is the packet which flows complementary to the Data Packet's flow. It is the packet which not only acts as the ACK for the previously received packets on the consumption side, but also provides the producer with the next offset to send data from.

Here is a description of what the different fields hold and mean :

Type - It holds the PacketType::ACK which distinguishes it from other packets and intimates the receiver of which packet it is receiving.

Offset - It holds an Integer Value which is the offset from which the Data is being requested. This also confirms that the data before this offset has been safely consumed.

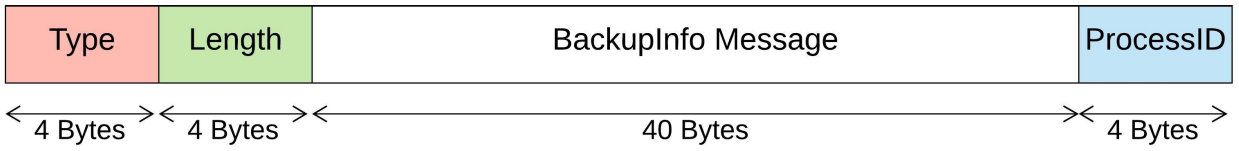

FIGURE 2.5: BackupInfo Packet

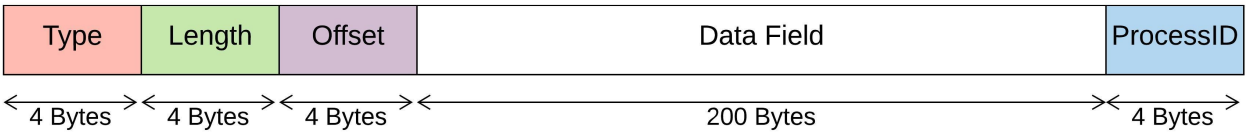

FIGURE 2.6: BackupData Packet

2.4 Backup Packets

Backup Packets are as the prefix suggests the packets which are send to the BACKUP Nodes. They are as can be seen very similar to the base packets with an extra payload of ProcessID. This ProcessID is very important to identify the Connection from which this packet has been received since the BACKUP Nodes receive Backup Packets from all Connections simultaneously.

BackupInfo Packet is the packet which a Data Channel sends the BACKUP Node before sending it Data for Backup. Here is a description of what the different fields hold and mean :

Type - It holds the PacketType::BACKUPINFO for distinction from other packets.

Length - It holds an Integer Value which is the actual size of the Info Message.

Info Message - Holds the Filename whose backup will be sent.

ProcessID - Holds the ProcessID of the Connection Channel.

BackupData Packet is the packet which a Data Channel sends the BACKUP Node containing the Data it has received from the PUT Client. Here is a description of what the different fields hold and mean :

Type - It holds the PacketType::BACKUPDATA for distinction from other packets.

Length - It holds an Integer Value which is the actual size of the Data sent for backup.

Data Field - Holds the data which needs to be backed up.

ProcessID - Holds the ProcessID of the Connection Channel.

Bibliography