Due: 12 March 2019 (Tuesday Week 3) by 2PM

COMP3221 Assignment 0: Introduction

The goal of this assignment is to help you familiarise yourself with the new version of the PASTA *system and understand the context of this year's programming assignments. This year, you will gradually implement a blockchain system as your assignments. Since it is a very advanced distrubuted system, we introduce the blockchain context in the remainder of this assignment. Upon completion of this assignment, you should have an overview of what a blockchain is, how many features are expected, and how to properly test and submit your work.*

1 What is a blockchain?

You may not have heard of blockchain before, but I bet you must have been surrounded with Bitcoin news these days. Bitcoin, is a *distributed system* offering a digital currency, called the *bitcoins*, created, used and verified independently of any central bank. It is guarded by cryptographic primitives and it recently gained momentum for no single person or government can fully control it. Thanks to being distributed, it has no single point of failure, can even tolerate attacks from multiple hackers. It offers *pseudonymity* in that users do not need to reveal their identity. Bitcoins used to be traded at extremely high prices but the market has gradually cooled down a bit. Many people around the world are currently providing this peer-to-peer service by mining bitcoins. Yet, bitcoin suffers limitations which make blockchain an interesting area of research. As a computer science student, you might be interested in knowing how Bitcoin works, and what system underneath supports the operation of Bitcoin. The answer is "blockchain".

Traditionally, the blockchain implements a distributed ledger as a chain of blocks, each block stores a series of transactions just like the page of a ledger. Recently, blockchain has found broader applications. People and companies started using blockchain for other purposes, like storing business contracts, recording medical patients history; some people even declared love and marriage on it. No matter how fancy its usage is, the goal of all blockchains remains the same—to maintain integrity of some information potentially indefinitely.

From a developer's perspective, the components of blockchain are nothing special. The data structure underneath is simply a linked list (that you might have seen or will learn about it in your data structure course) that represents the chain of blocks. The distributed system is built upon a peer-to-peer (P2P) network (that you will learn in this course). To make records consistent on each participant's computer, you will learn about consensus algorithms. Some security mechanisms like encryption and digital signature will be used to provide confidentiality and authentication. By combining these four building blocks, you will be able to create a blockchain yourself!

2 How many features are expected to implement during the semester?

The blockchain core data structure (Linked list + P2P network) is required. While a fully functional blockchain typically requires various additional features to ensure security, consistency, etc., in this project, we will just implement one simple security feature to make the blockchain tamper-proof. A tamper-proof blockchain is achieved using hash pointers between blocks as links of the linked list.

2.1 Hash function

Before talking about how hash pointers are used in the linked list, let me give you a quick introduction of hash functions. A hash function is a special class of function that given an arbitrary object as input, produces the output which is a fixed length of bits. Those output bits are called the hash value. A good cryptographic hash function has three important properties:

2.1.1 Pre-image resistance

Given a hash value h = hash(m), it should be difficult to find the original message m.

2.1.2 Second pre-image resistance

Given an input m1, it should be hard to find another input m2 (not equal to m1) that generates the same hash value hash(m1) = hash(m2).

2.1.3 Collision resistant

It is hard to find two distinct messages m1, m2 that hash to the same output hash(m1) = hash(m2).

Cryptographic hash functions are commonly used in various computer systems and protocols. They provide a strong guarantee that if an attacker somehow changes the message, then the new hash value of the tampered message will be different to the original hash value. The victim could easily validate the message by checking if two hash values match each other.

How to build a good cryptographic hash function and show its mathematical proof is beyond this course. But with the help of J ava security library. It is simple to calculate the hash value with standard hash functions, like the SHA-256 hashing algorithm used in this course. Below is the code to calculate an SHA-256 hash of message **12345** and print the hash value encoded in base64 encoding.

```java
import java.io.ByteArrayOutputStream;
import java.io.DataOutputStream;
import java.io.IOException;
import java.security.MessageDigest;
import java.security.NoSuchAlgorithmException;
import java.util.Base64;

public class Assignment0 {

    public static void main(String []args) {
        System.out.println(hashMessage("12345"));
    }

    public static String hashMessage(String message) {
        String hashString = "";
        try {
            MessageDigest digest = MessageDigest.getInstance("SHA-256");

            ByteArrayOutputStream baos = new ByteArrayOutputStream();
            DataOutputStream dos = new DataOutputStream(baos);

            dos.writeUTF(message);
            byte[] bytes = baos.toByteArray();
            byte[] hash = digest.digest(bytes);
            hashString = Base64.getEncoder().encodeToString(hash);
        } catch (NoSuchAlgorithmException e) {
            e.printStackTrace();
        } catch (IOException e) {
            e.printStackTrace();
        }
        return hashString;
    }


}
```

Before going on, let me give you your first assignment (Assignment 0) to test your understanding so far.

Task 1 hash an array of messages

Using the skeleton code below, try to compute the hash of an array of messages.

Hint: You should not concatenate messages into a single string, and then write the string to **`DataOutputStream`**. Instead, you should use a for loop to write messages inside the array to **`DataOutputStream`** one by one. The order to write messages into **`DataOutputStream`** should be the same order as messages stored in the array.

```java
import java.io.ByteArrayOutputStream;
import java.io.DataOutputStream;
import java.io.IOException;
import java.security.MessageDigest;
import java.security.NoSuchAlgorithmException;
import java.util.Base64;
import java.util.ArrayList;

public class Assignment0 {

    public static void main(String []args) {
        ArrayList<String> messages = new ArrayList<>();
        messages.add("12345");
        messages.add("12345");
        System.out.println(hashMessages(messages));
        // you should see the hash value calculated is
        // 7ccQDEgOM+OWvega620WYCXJHs1w53wSumP329xFirw=
    }

    public static String hashMessages(ArrayList<String> messages) {
        String hashString = "";
        try {
            MessageDigest digest = MessageDigest.getInstance("SHA-256");

            ByteArrayOutputStream baos = new ByteArrayOutputStream();
            DataOutputStream dos = new DataOutputStream(baos);

            // write you code here

            byte[] bytes = baos.toByteArray();
            byte[] hash = digest.digest(bytes);
            hashString = Base64.getEncoder().encodeToString(hash);
        } catch (NoSuchAlgorithmException e) {
            e.printStackTrace();
        } catch (IOException e) {
            e.printStackTrace();
        }
        return hashString;
    }


}
```

2.1.4 Submission

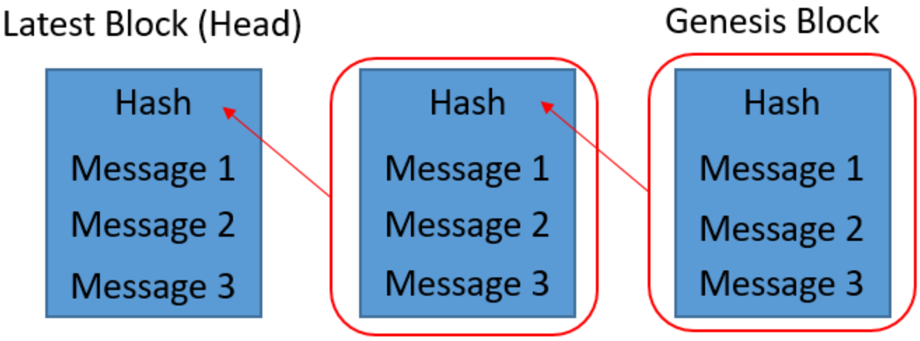
PASTA will be used for automated marking. Please put all source codes(*.java) under **src** folder and zip the **src** folder to submit your solution on PASTA (https://pastpd01191.srv.sydney.edu.au/PASTA/). The archived file should be named **src.zip**. Please remove all test cases or class files(*.class) before submitting.

To access PASTA, you will have to connect to University of Sydney network (on campus or through VPN). Instructions on setting up VPN to connect to university network can be found here: http://staff.ask.sydney.edu.au/app/answers/detail/a_id/519/session/L2F2LzEvdGltZS8xNTUxMDc3NzQ0L3NpZC9DSjJ0aWY4bw%3D%3D.

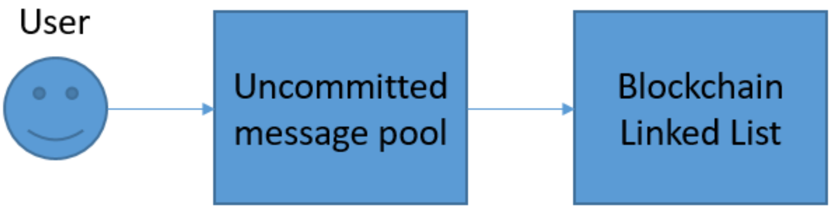
This assignment counts for 0 mark but you're required to finish it as it is crucial for future assignments.

2.2 Linked list

Now, it is time to create our first linked list using hash pointers. Like typical linked lists, we have nodes and pointers. Each block (node) in the blockchain has usually two types of fields. The first are the messages stored in the block. The second is the block pointer. Blockchain utilizes the hash value of the previous block as the pointer. Its structure is as follows.



A blockchain uses the linked list shown above to store committed messages. A committed message is a message that has been permanently stored in the blockchain, and there is (presumably) no way to change it in the future.[1] Suppose an attacker would like to change one of the messages in an intermediate block. In order to make sure the chain is correctly linked, the attacker also needs to update the hash value stored in the next block, and the hash value stored in the next next block, and so on until the latest block. This indicates that every change made on the old messages will have an impact on the latest hash value. Just by checking the latest hash value, you can confidently tell if any tampering happened before. Uncommitted messages are stored in another pool. Once the pool meets certain criteria, messages in the pool get committed, and a new block is formed in the blockchain.



Once you have mastered how to construct the blockchain using hash pointers, you are ready to start implementing the next core building block, that is the P2P network. But, no need to hurry! We are going to teach you how to do this step by step during the semester.

[1] You will see later in this course under what assumptions this can be ensured.

3 How to properly test and submit my work?

To test your code, you are encouraged to write your test cases and thoroughly test them before submitting your code. There are three reasons for that. First of all, as a developer, you should be responsible for everything you wrote, and testing improves your confidence. Secondly, since the test is designed by yourself, it is a white-box testing rather than a black-box testing PASTA provides you. You can fix your bugs quickly. Thirdly, there will be a lot of students testing their code on PASTA when approaching the deadline and the waiting queue could be long in case the server becomes overloaded. You may have to wait a long time before your code gets tested, it could translate in a waste of your time if you realise afterwards that there was a small typo in your submission...

If you need some extra help on the assignments or lecture materials, the discussion forum is the place to ask questions. Everyone is welcomed to post questions on the forum. We do not expect you to send emails directly to the lecturer or tutors, because your questions may also be valuable to other students.

Typically we are getting tons of questions during the submission deadline. To cope with this, we subdivided assignments into tasks. Assignments have hard due dates, which means every submission made after the assignment due date will have a penalty. Tasks, in contrast, have a soft due date. You are encouraged to finish it before the soft due date. But you could catch up later in case you are busy that week (no later than assignment due date). It helps you organize your time and distribute your load. If you found any ambiguity in the assignment specification, please inform the TA via emails or post it on the discussion form as soon as possible.) *The due date will not be postponed.* Once again, please organize your time wisely. Finishing assignments in one night before the deadline is not feasible.

The submission system we use this semester, as usual, is PASTA. PASTA experienced a major update for this semester. We are keen for any suggestions on the new PASTA system. Should you have any feedback regarding the PASTA system, please do not hesitate to contact the TA(yhua7740@uni.sydney.edu.au) directly. Assignment 0 is precisely to test that you could properly use PASTA. After Assignment 0, we will not accept excuses that a student is not familiar with PASTA.