Distributed Consensus

Simulator for
Sleepy Consensus Protocol

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Instructor

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- **Where to find our project?**

  https://github.com/initc3/sleepysim   SleepySim

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1 Introduction

Consensus protocol serves as the core of distributed computing and also provides a foundational building block for cryptocurrency protocols. In traditional cryptocurrency schemes, proof-of-work (PoW) is leveraged to provide consistency and chain quality for the underlying blockchain. However, proof-of-work is notoriously indifferent for its waste of energy and the potential of the computing power centralization. To face this issue, proof-of-stake (PoS) is proposed to replace proof-of-work. In Pass and Shi's *sleepy consensus* article (eprint 2016/918) [1], a PoS protocol is constructed to realize consensus on the linearly ordered log abstraction – often referred to as state machine replication or linearizability in the distributed systems literature. This scheme is named as sleepy consensus protocol, which respects two important resiliency properties, i.e., consistency and liveness. Moreover, in sleepy consensus model, players can be either online (alert) or offline (asleep), and their online status may change at any point during the protocol execution.

Algorithm 1 presents how sleepy consensus protocol works. The protocol takes a parameter p as input, where p denotes the probability each node is elected leader in a single time step. All nodes that just spawned will invoke the init entry point. During initialization, a node generates a signature key pair and registers the public key with the public-key infrastructure F_{CA}.

Algorithm 1 Sleepy Consensus Protocol

If On Initialization:
1: Let $(pk, sk) := \sum.\text{gen}()$
2: Register pk with F_{CA}
3: Let $chain := genesis$
If On Received $chain'$:
4: Assert $|chain'| > |chain|$ and $chain'$ is valid w.r.t. eligible and the current time t
5: $chain := chain'$ and gossip $chain$
Every Time Step:
6: Receive input transactions(txs)
7: Let t be the current time
8: **if** eligible$^t(P)$ where P is the current node's party identifier **then**
9:     Let $\sigma := \sum.\text{sign}(sk, chain[1].h, \text{txs}, t), h' := d(chain[1].h, \text{txs}, t, P, \sigma)$
10:     Let $B := (chain[1].h, \text{txs}, t, P, \sigma, h')$, let $chain := chain||B$ and gossip $chain$
11: **end if**
12: Output $extract(chain)$ to Z where $extract()$ is the function outputs an ordered list containing the txs extracted from each block in $chain$
Subroutine eligible$^t(P)$:
13: **if** $H(P, t) < D_p$ and P is a valid party of this protocol. **then**
14:     **return** 1
15: **else**
16:     **return** 0
17: **end if**

Now, the sleepy protocol proceeds very much like a proof-of-work blockchain, except that instead of solving computational puzzles, in this protocol a node can

extend the chain at time t iff it is elected leader at time t. To extend the chain with a block, a leader of time t simply signs a tuple containing the previous blocks hash, the nodes own party identifier, the current time t, as well as a set of transactions to be confirmed. Leader election can be achieved through a public hash function H that is modeled as a random oracle. The difficulty parameter D_p is defined such that the hash outcome is less than D_p with probability p. For simplicity, here we describe the scheme with a random oracle H – however as we explain in this section, H can be removed and replaced with a pseurdorandom function and a common reference string.

In this document, we build a simulator for monitoring the real-world performance of sleepy consensus protocol by constructing a framework which implements Algorithm 1, as well as imitating behaviors of honest players and corrupted/adversarial players in the meanwhile. After analyzing the simulating results, **we know ... add text here**

This document is organized as follows. In Section 2, we introduce the framework of simulator. In Section 3, we present how honest players work while simulating. And in Section 4, we imitate the adversarial players' behavior and attack the sleepy consensus protocol by several algorithms. We give the analysis of simulating results in Section 5. Finally, we draw conclusions in Section 6.

2   The Framework of Simulator

In this section, we will illustrate the construction of the framework of our simulator, which includes **add text here**

2.1   Controller

...

3   The Imitation of Honest Players

3.1   Algorithm for Honest Players

In our program, the honest nodes use the algorithm of sleepy consensus. To be specific, There are some steps for the algorithm.

- First, the nodes will elect a leader using the hash function of identity and current time. If
$$H(identity, currenttime) < D$$
, where D denotes difficulty, then $Node[identity]$ will be elected to be a leader.

- Second, the leader can sign the block using the hash value of previous block, transactions and time, then broadcasts.
$$Block = sign(sk, block, Trans, time)$$

– When one honest node receive a new chain, if the time in block is strictly increasing and the time in the blocks is not in the future, it will update its chain with the new chain.

3.2   The process to simulate sleepy consensus

There are several steps to simulate the algorithm of sleepy consensus in our program.

– First of all, in every round, the controller will let every node to run.

– Second, the honest node will ask network controller for messages.

– Third, the network controller will send related message to every node.

– Then every honest node will ask the controller whether it has been elected a leader.

– Next, if one honest node is not elected to be a leader, it will do nothing. However, if it is a leader, it will sign one new block using its secret key with the hash value of previous block, transactions and time stamp. Then it will broadcast it.

– Finally, whatever one honest node has done, it will give some feedback to controller and network controller.

4   The Imitation of Adversarial Players

The previous section introduces the implementation of the honest players' behavior under the sleepy consensus protocol in simulator. This section, in contrast, will present the imitatation of the adversarial players' behavior, which aims to hinder the normal functioning of sleepy consensus protocol under current framework structure. And we design four different attacking algorithms to try to break the consensus between different nodes, i.e., players in the distributed system. What should be noticed is that the adversaries cannot betray the rules established by the framework, while they can only control the network message transportation, i.e., intercepting and delaying the message from honest players. Also, an adversary can manipulate several corrupted nodes in the system, by which adversary impose damage to the system under sleepy consensus protocol.

To simulate the attacks, we assume there is an an adversary lurking within the framework, who owns competence to intercept all messages coming from honest nodes and decide which to delay in the transportation. Also, the adversary is able to access useful information from these message to fork blocks right behind the private chain he captures. Based on above setting, we design four attacking methods for adversary to smash the consensus holded by system, which are illustrated in following subsections.

4.1   Naïve Adversary Attack

The *Naïve Adversary Attack* corresponds to an attacking method that is quite simple and easy to be came up with when knowing how the sleepy consensus protocol works. Figure 1 illustrates how naïve adversaries to break the consistency of sleepy consensus. In this figure, when honest players add blocks to the main chain which they think is longest (that is the reason why there are several folks in Figure 1 – blocks linked by dashed arrows), adversaries mine their own private chain and check whether the length of longest added blocks is larger than security parameter T in every time step. If the longest chain added by honest nodes has length larger than T yet smaller than the length of private chain mined by adversaries, the attacker can, just like the red arrow in Figure 1, add their private chain to a specific block in public chain and thus damaging the consistency of sleepy consensus, since some blocks which are confirmed be fixed in main chain are replaced by blocks forged by adversaries.
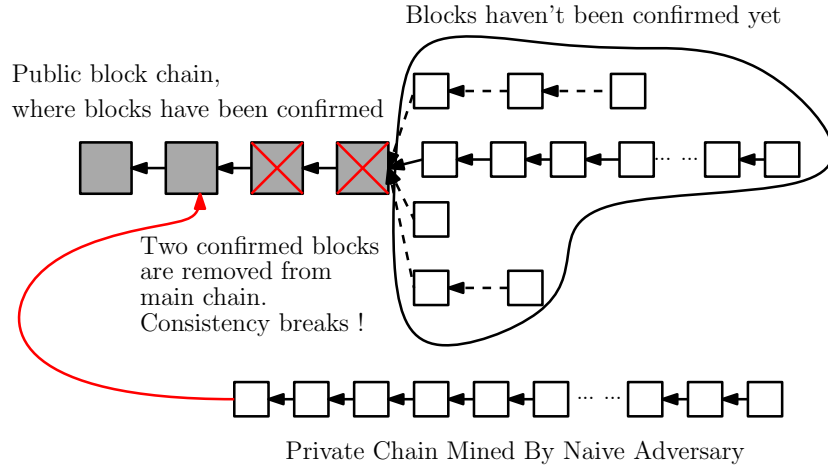

Fig. 1. This figure represents the attack which naïve adversaries impose to the sleepy consensus. The consistency of consensus will break when the length of private chain mined by adversaries is larger than the length of the longest private chain mined by honest nodes, and the later one is supposed be larger than security parameter T, which denotes the time round number a block can be confirmed as secure, i.e., be eternally fixed in main block chain.

4.2   Selfish Adversary Attack

The selfish adversary attack is integrated with the concept of *selfish mining*, which is proposed by Eyal et al. [2]. To illustrate, if everyone adheres to the sleepy consensus protocol, then a node with computation power of 10% should also get 10% profit from mining for expectation. However, the aim of selfish mining is to waste honest nodes' computation power and increase its revenue for mining blocks.

The operation of this attack are quite simple. Firstly, adversaries will mine a private chain and hide it from the rest. If the honest node mines a block from the public main chain, then adversaries will publish their private block immediately and delibrately creating a fork in the network. Otherwise, adversary will keep mining on their private chain. To be more specific, if currently the private chain has led the public chain by length of two, then if a new public block is discovered, adversaries would likely to publish all of their two private blocks, thus making their chain the longest chain in the network. If the private chain has led the public chain by length more than two, then for every newly discovered public block, adversaries will publish one of their private blocks to create forks in the network. We can imagine that through making forks in the network, computation is dispersed and also wasted. Thus, the adversary can gain more than he deserves.
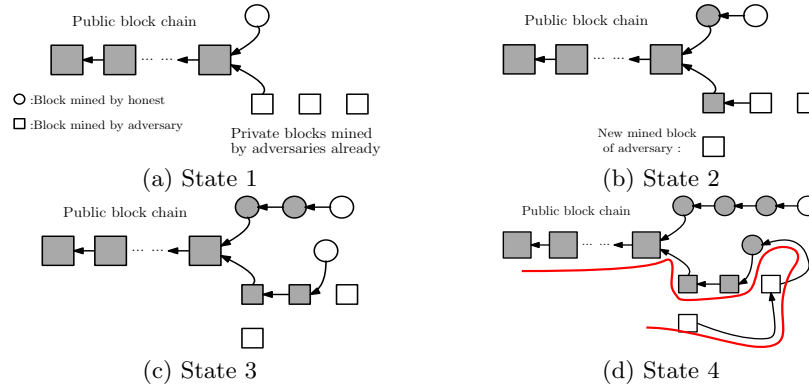

Fig. 2. This figure shows an example to illustrate how selfish adversary algorithm works. Four subfigures respectively correspond to four different states in one selfish attack.

Figure 2 presents an instance of selfish adversary attack. First of all, in Figure 2(a), the system is initialized with one public block chain, and both honest and adversary players want to add block to the public block chain. In state one, adversaries have already mined three blocks. And according to selfish attack algorithm, they will make a folk chain with same length of longest chain in current state, when one honest player adds his mined block to public chain. Figure 2(b) shows the state 2 when new honest player adds block to the public chain branch he selects. And adversaries need to release another private block he holds to keep the chain he works on has the same length of the longest chain in system. What should be noticed is in state 2, adversaries mined a new private block. In Figure 2(c), i.e., state 3, two honest players come in and add blocks. However, in this state, one player select the branch where adversaries work on as the longest chain while another does not, which causes two longest branches are still with same length. Therefore, in state 3, adversaries just keep mining while add no block to the main chain. In Figure 2(d), i.e., state 4, one honest node comes in and chooses the longest chain he prefers. And adversaries still need to add block to the chain they works on to keep the equivalence of length. However,

in this case, adversaries only have one block left. Thus in line with algorithm, they need to release that block and add it to their branch to make sure their chain is now the sole longest chain in system – just as red line in Figure 2(d) represents. And from then on, both honest nodes and adverseries will select the chain underlined in red color as public chain to keep mining.

4.3   Stubborn Adversary Attack

4.4   Selfish Eclipse Attack

5   The Analysis of Simulating Results

Here is the analysis of Simulating Results.

6   Conclusion

In conclusion....

References

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2. Eyal, I., & Sirer, E. G. (2014, March). Majority is not enough: Bitcoin mining is vulnerable. In *International conference on financial cryptography and data security* (pp. 436-454). Springer, Berlin, Heidelberg.