Discrete-event Simulator for a P2P Cryptocurrency Network

COL 867 - Assignment 1

Group No. 24

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Implementation Details

We've implemented the assignment in Python, and tested it on Ubuntu machines.

The core of the simulation is a priority queue which holds events prioritized by their scheduled time. There are 4 types of events: Transaction Generate, Transaction Receive, Block Generate, Block Receive.

Since nodes keep generating events and the simulation is potentially infinite, we used a limit on the number of events that are run. This can also be passed as a parameter to the program.

At the end of the simulation, each node dumps its blockchain tree in the DOT graph description language, which are rendered into .png images using the Graphviz tool. We also created a graph depicting the connections between nodes to visualise the network.

Running the code:

In the source directory, run: `python3 run.py [n] [z] [tm] [bm]`

Where, n is the number of nodes, z is the fraction of slow nodes and tm, bm are the mean transaction & block interarrival times respectively.

By default, simulations run for a maximum of 1000 events. To change that pass `--until` parameter and to suppress printing of event log use `-q`:

For eg: `python3 run.py 10 0.3 3 10 -q --until 5000`

Generated charts are stored in **output** directory.

Theoretical reasons of choosing the exponential distribution for inter-arrival between transactions:

The question concern with the time we need to wait before a given event (generate transaction) occurs. If this waiting time is unknown, it is often appropriate to think of it as a random variable having an exponential distribution. Roughly speaking, the time X we need to wait before an event occurs has an exponential distribution if the probability that the event occurs during a certain time interval is proportional to the length of that time interval. More precisely, X has an exponential distribution if the conditional probability:

$$P(t < X \leq t + \Delta t | X > t)$$

is approximately proportional to the length of Δt the time interval comprised between the times t and $t + \Delta t$, for any time instant t. In most practical situations this property is very realistic and this is the reason why we choose the exponential distribution for waiting time for generation of next event (transaction).

One of the most important properties of the exponential distribution is the **memoryless property.** When the event can occur more than once and the time elapsed between two successive occurrences is exponentially distributed and independent of previous occurrences, the number of occurrences of the event within a given unit of time has a Poisson distribution. The exponential distribution is also related to the Poisson distribution.

Justification for chosen distribution for connecting each node to a random number of other nodes:

We are using **Uniform Distribution** with minimum value as $n/2$ and maximum value as n. The constraints on the range ensures that the graph is always connected.

Note: We are not considering every possible connected graph. We are merely ensuring that the graph we create is connected.

For latency calculations, Why is the bottleneck link speed considered:

In real world scenario, the transmission depends on bandwidth. So to simulate that we use bottleneck link speed in latency calculation.

For latency calculations, Why does D_{ij} mean depend on C_{ij}:

The bottleneck link speed C_{ij} determines how fast a node is able to process its queue which in turn will determine the queue delay each message will have. Therefore D_{ij} mean will depend upon C_{ij}.

Justification for chosen mean value of Tk, when generating new blocks:

T_k (or $\mathbf{B_m}$) is the mean wait time for generation of blocks. So higher value of T_k would result in fewer blocks being generated and vice-versa.

If we have too many blocks the number of transaction per block is reduced, whereas if we have too few blocks then node transaction queue is filled up. So we need a balance between the two

Summary of effects of choosing different values of simulation parameters:

Number of Nodes (N):

With z value fixed (z = 0.3), we observe the following.

- When n = 8, the chain lengths of slower nodes relatively same as that of faster nodes.
- As n value increases the difference between chain lengths of slower nodes and faster nodes increases, with faster nodes having longer chains.
- With even higher values of n (~20), the slower nodes have very short chain lengths as compared to the faster nodes.

Fraction of Slow Nodes (Z):

With n value fixed (n = 10), we observe the following.

- When z = 0.1, i.e. 10 % nodes are slow, the longest chain length of slow nodes is much shorter than that of the faster nodes.
- As z increase the chain lengths of the slower nodes starts catching up to the faster nodes.
- At around z = 0.7 to 0.8 the slower node chain length is almost the same as faster nodes.

Mean transaction interarrival time (T_m):

With N = 10, Z = 0.3, B_m = 10, and running simulation for 5000 events, we observe:

- When $\mathbf{T_m}$ = 1, a lot of transactions are generated, resulting in the events queue being flooded with TransactionReceive events (66% of all events)
  This in turn results in not a lot of blocks getting propagated and the trees at all nodes are relatively sparse.
- As $\mathbf{T_m}$ is increased the trees all nodes get relatively denser since lesser number of TransactionReceive events happen.

In general, increasing $\mathbf{T_m}$ results in less transactions being generated for every node and vice versa.

Mean block interarrival time (B_m):

With N = 10, Z = 0.3, T_m = 5, and running simulation for 5000 events, we observe:

- When $\mathbf{B_m}$ = 1, a lot of blocks are generated in a relatively small amount of time and since nodes aren't waiting to hear from other nodes and start extending the longest chain they have, the branching factor of the resulting tree is high at both slow and fast nodes as a result of which the maximum chain length is relatively low.

- As $\mathbf{B_m}$ is increased to be the branching factor of the tree decreases and the chains start getting relatively longer.

In general, increasing $\mathbf{B_m}$ results in less blocks being generated for every node and vice versa.

Summary of the structure of trees for different types of nodes:

Fast: Block chain is of longer length.

Slow: Block chain is of shorter length.

Faster nodes basically have a high speed network among themselves, as such they are able to receive more blocks than the slower nodes, so they have a longer chain length.

Low CPU (high B_m): The branching factor is lower

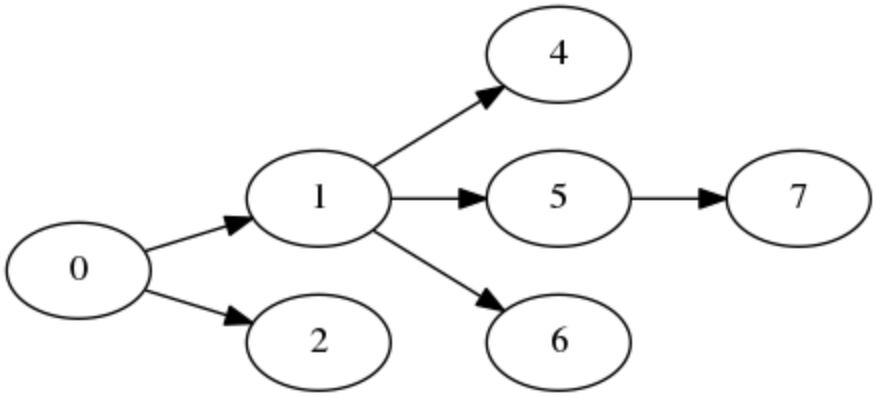
High CPU (low B_m): The branching factor is higher

If nodes have higher CPU power, they are able to generate more blocks in less time intervals so more duplicate blocks are generated that leads to more forks in the tree. As such the branching factor is higher.

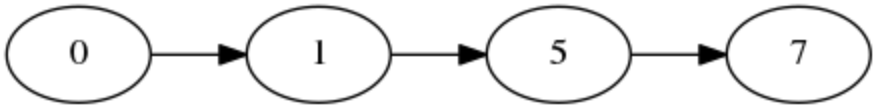
Pictures of typical trees

With parameters, N = 10, Z = 0.3, $\mathbf{T_m}$ **=** 3, $\mathbf{B_m}$ **=** 10 and running the simulation for 2000 events, we observe the following blockchain trees.

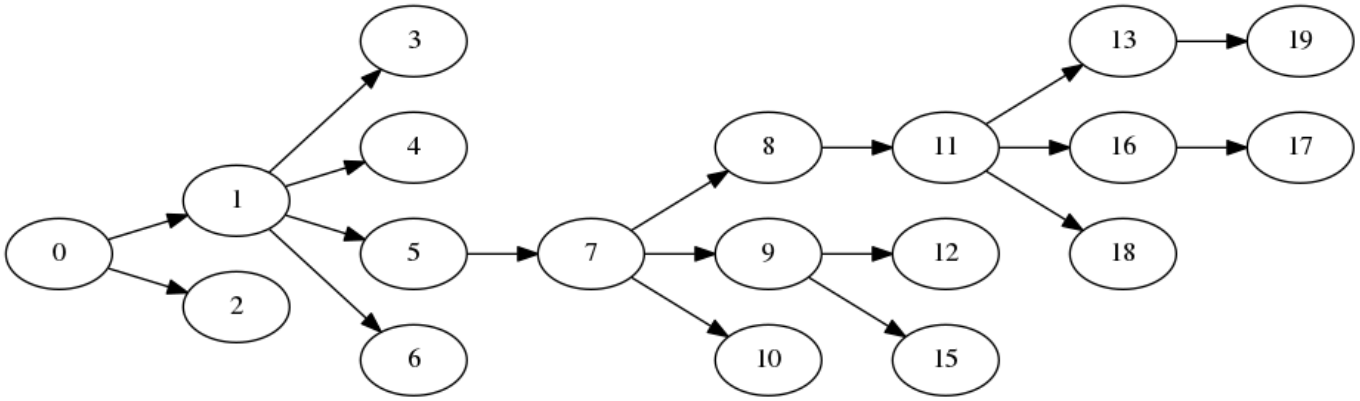
On a slow node:



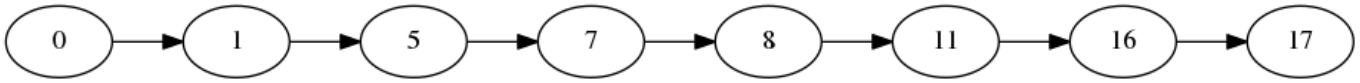
The pruned tree (showing the longest chain):



On a fast node:



The pruned tree (showing the longest chain):



This shows how fast nodes have denser trees and longer chains because they have the network advantage.

When lowering $\mathbf{B_m = 1}$, we get high branching factors and shorter chains: