DISTRIBUTED CONWAY'S GAME OF LIFE SIMULATION

CMPT431 Final Presentation

Background Introduction

- The Game of Life is a visualized cellular automaton devised by the British mathematician John Horton Conway in 1970.
- The universe (board) of the Game of Life is a two-dimensional orthogonal grid of square cells.
- Each cell has three states:
  - Survival
  - Death
  - New Birth

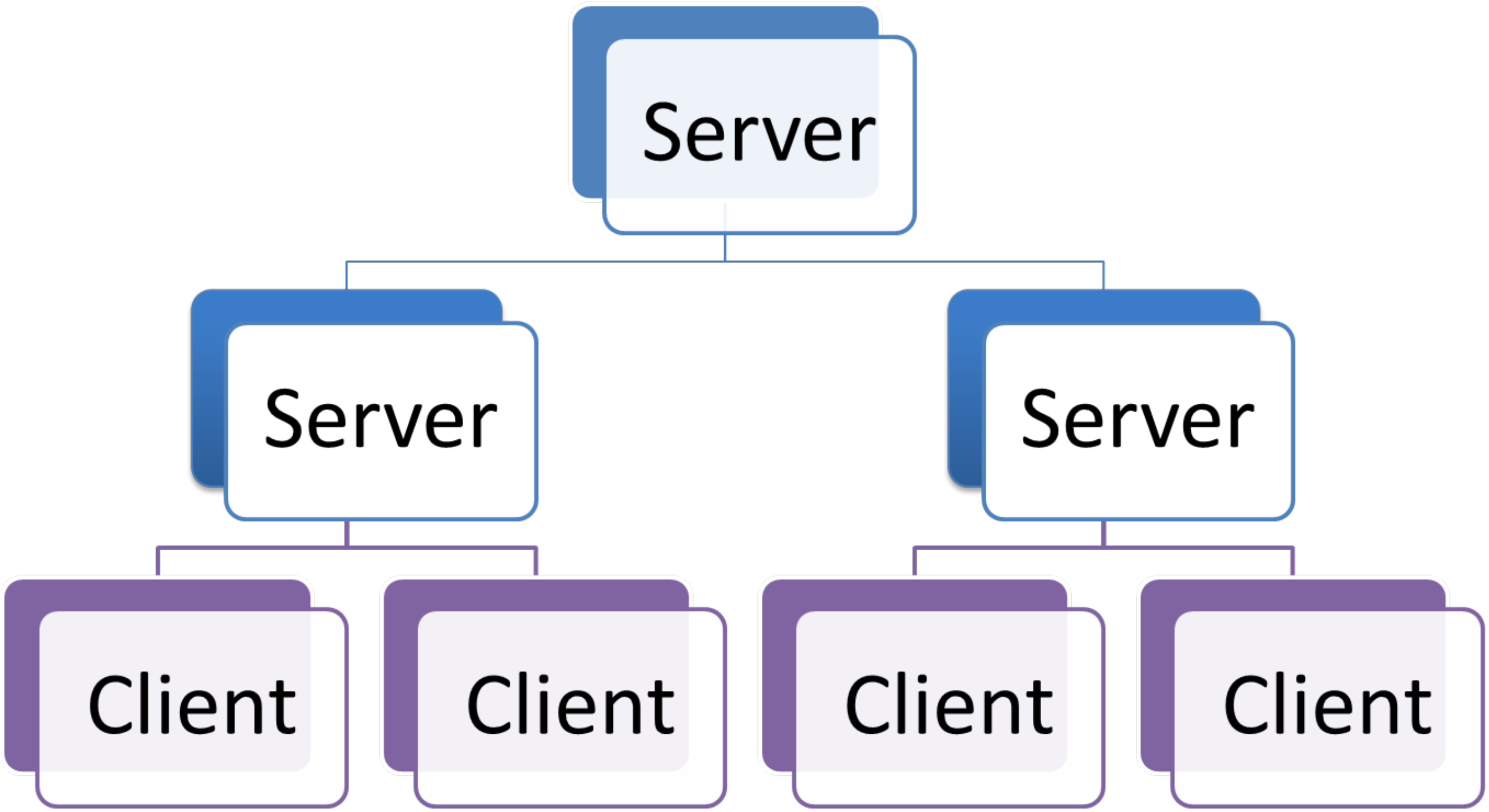
Objective

- Implement a distributed Conway's Game of Life computational simulation
- Handle large-size packetized network messages
- Build a graphical interface to visualize the universe
- Support over 100,000,000 cells and 10,000,000 lives
- Support dynamically adding and deleting computing nodes
- Finish one cycle with 100,000,000 cells within 0.25 sec

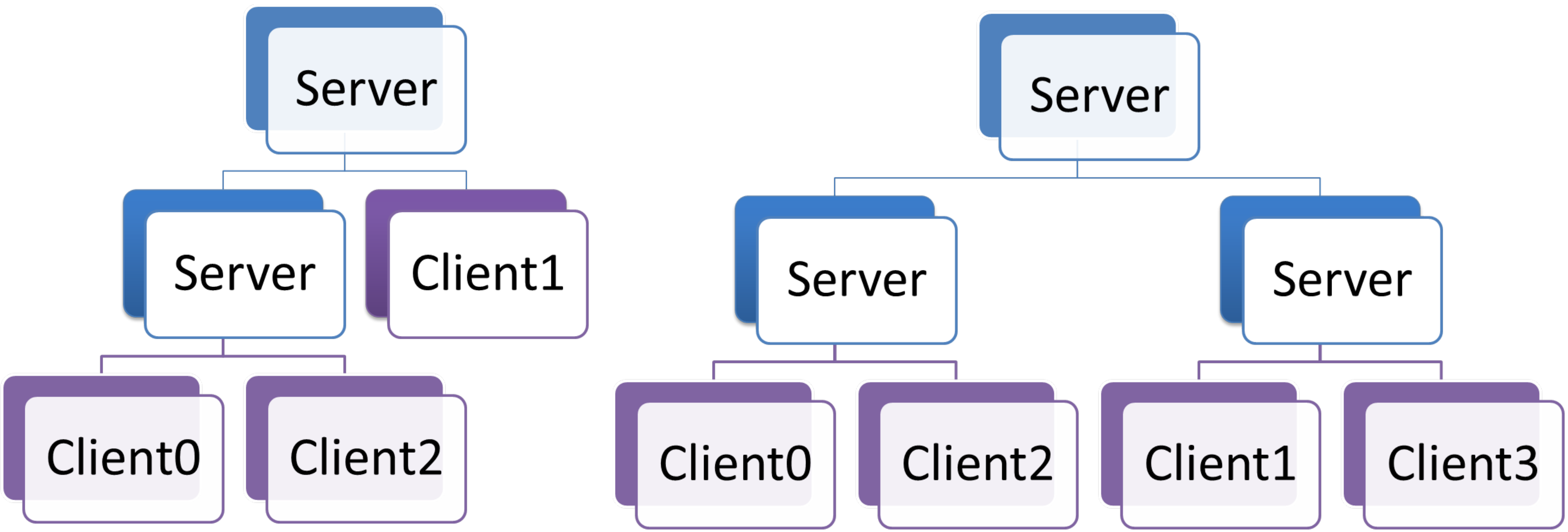
Challenges

- Computing nodes must exchange information to coordinate with each other
- Various messages must be designed to help implement dynamically adding and deleting nodes
- Server must take control to the computing nodes to guarantee transitions occur simultaneously
- Network messages should be minimized in order to avoid the system becomes network-bound with only a few computing nodes

Structure



Adding


Server
Server
Client1
Client0
Client2
Server
Server
Server
Client0
Client2
Client1
Client3

Adding(cont.)

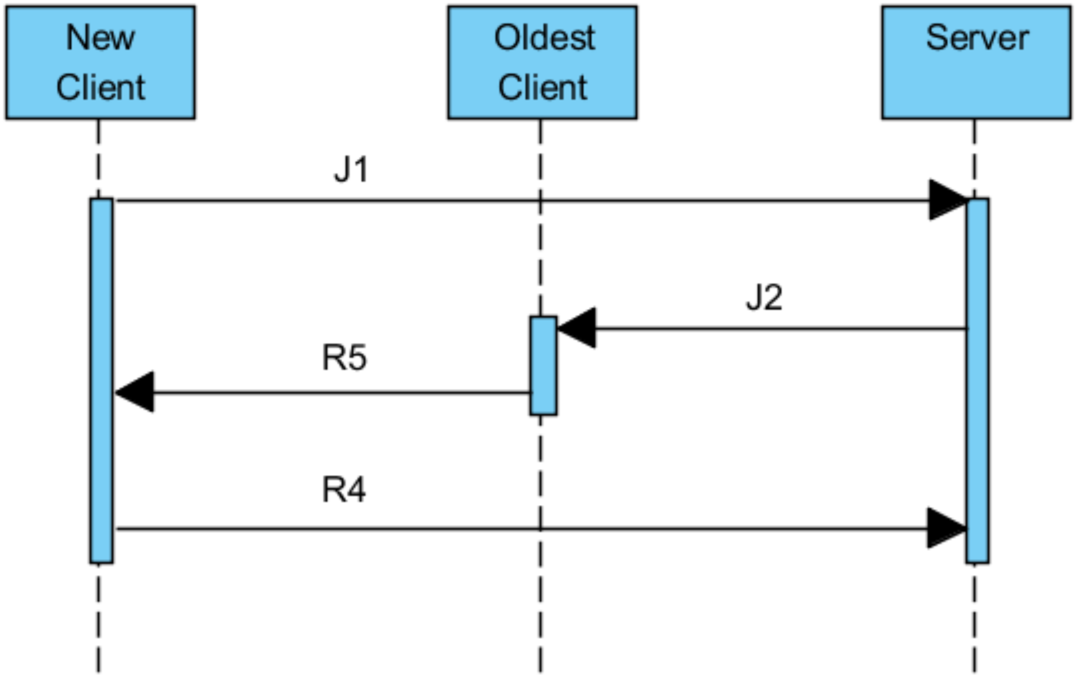
- A wants to join (first client)
  - A => Server: application
  - Server => A: accepted & data
  - A => Server: received

Adding (cont.)

- A wants to join (general)
  - A => Server: application
  - Server => B (*): ask B to work with A
  - B => A: accepted & data
  - A => B: received
  - B => Server: everything is done

*B is the first node who has no siblings; if everybody has, then choose first node.

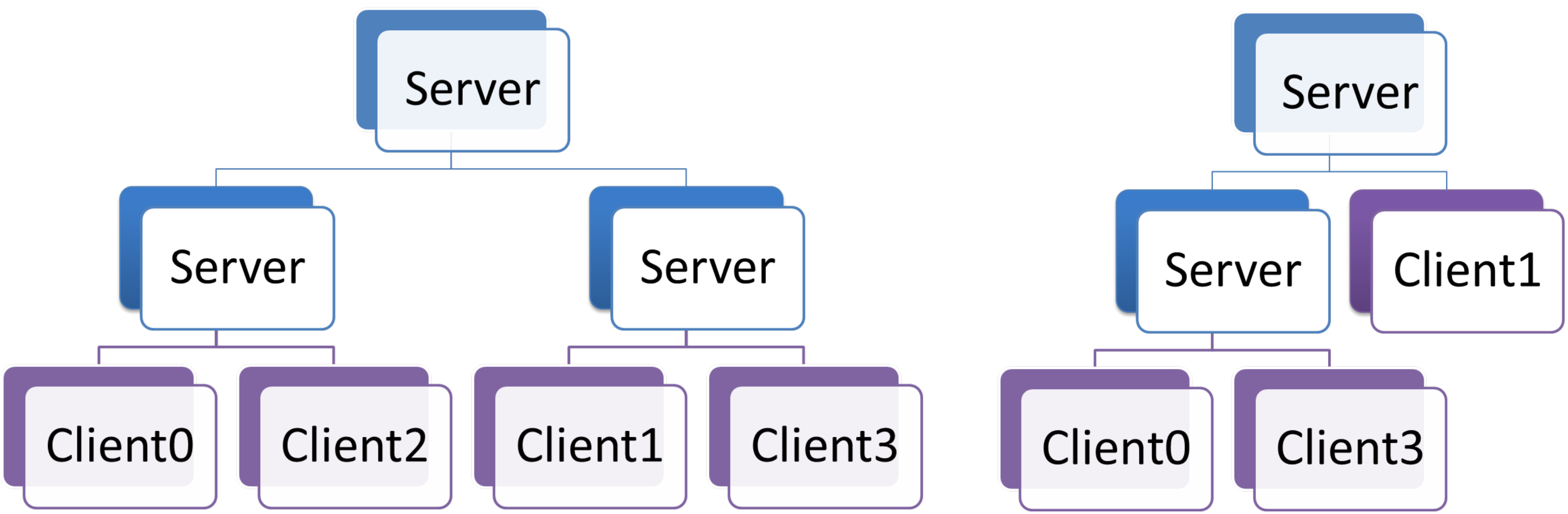
Adding (cont.)



Message Passing

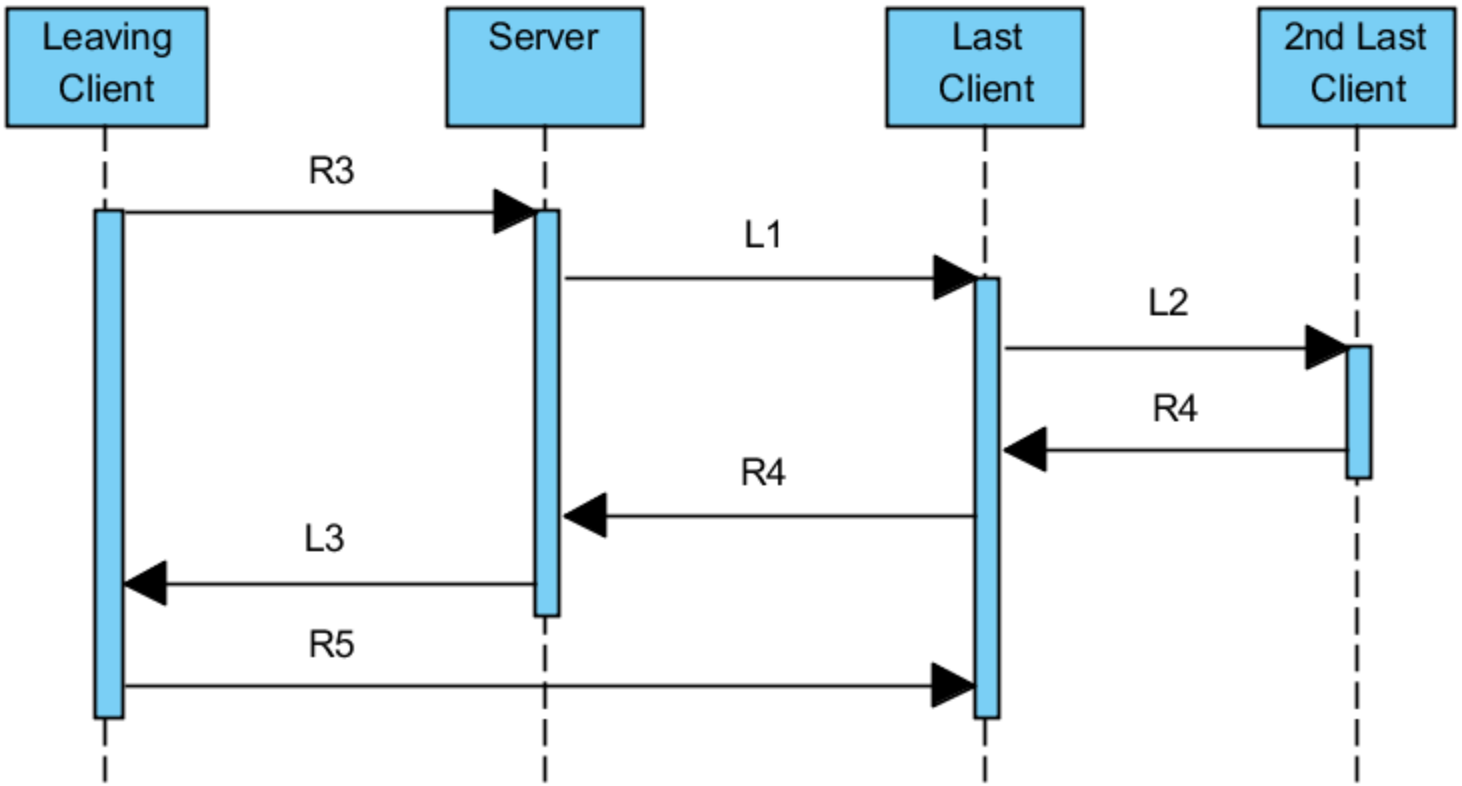
Message		Direction	Payload	Description
R1	Next Clock	S→C	new clock number	Inform all the clients to start new computation round
R2	Border	C→C	border status vector	Send border information to clients that is in charge of adjacent area
R3	Report	C→S	whether is leaving, top and left coordinate, status bit map	Report finished computation, and return the computation result to the server in interactive mode
R4	Confirm	A→A	none	Confirm received last message
R5	New Outfit	C→C	connection information, outfit information	Send all the computing information to a new added client
R6	Neighbor Update	C→C	connection information, relative position	Inform all the neighbors about the position change
J1	Request Join	C→S	connection information	Send request to server for joining the computation system
J2	Split	S→C	connection information, new client id, split direction	Inform the right client to split its area, construct the new outfit and send to the new client
L1	Last Merge	S→C	connection information	Inform the last two client to merge into one, the idle one waits for new command
L2	Outfit Merge	C→C	connection information, outfit	Send outfit to pair client for merging
L3	Leave Permit	S→C	connection information	Send outfit to the specified client

Leaving



Server
Server
Server
Client0
Client2
Client1
Client3
Server
Server
Client1
Client0
Client3

Leaving(cont.)



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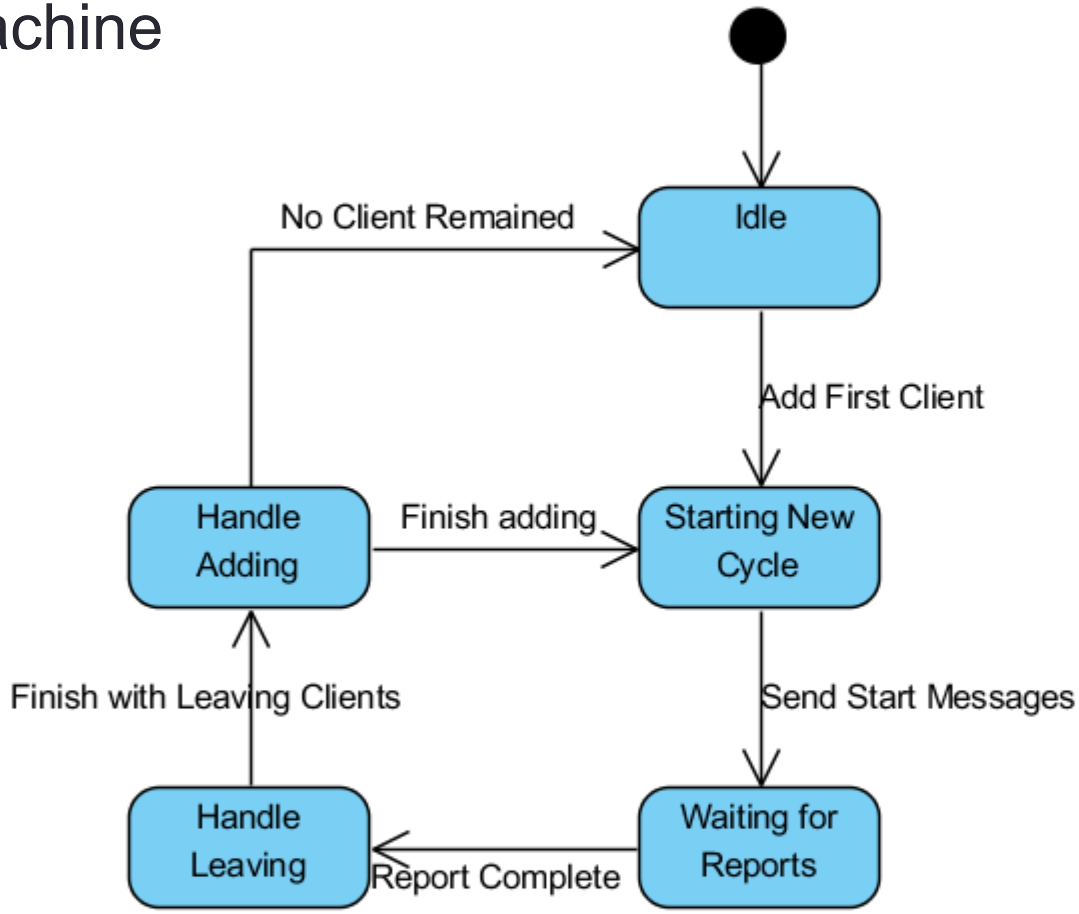
Server

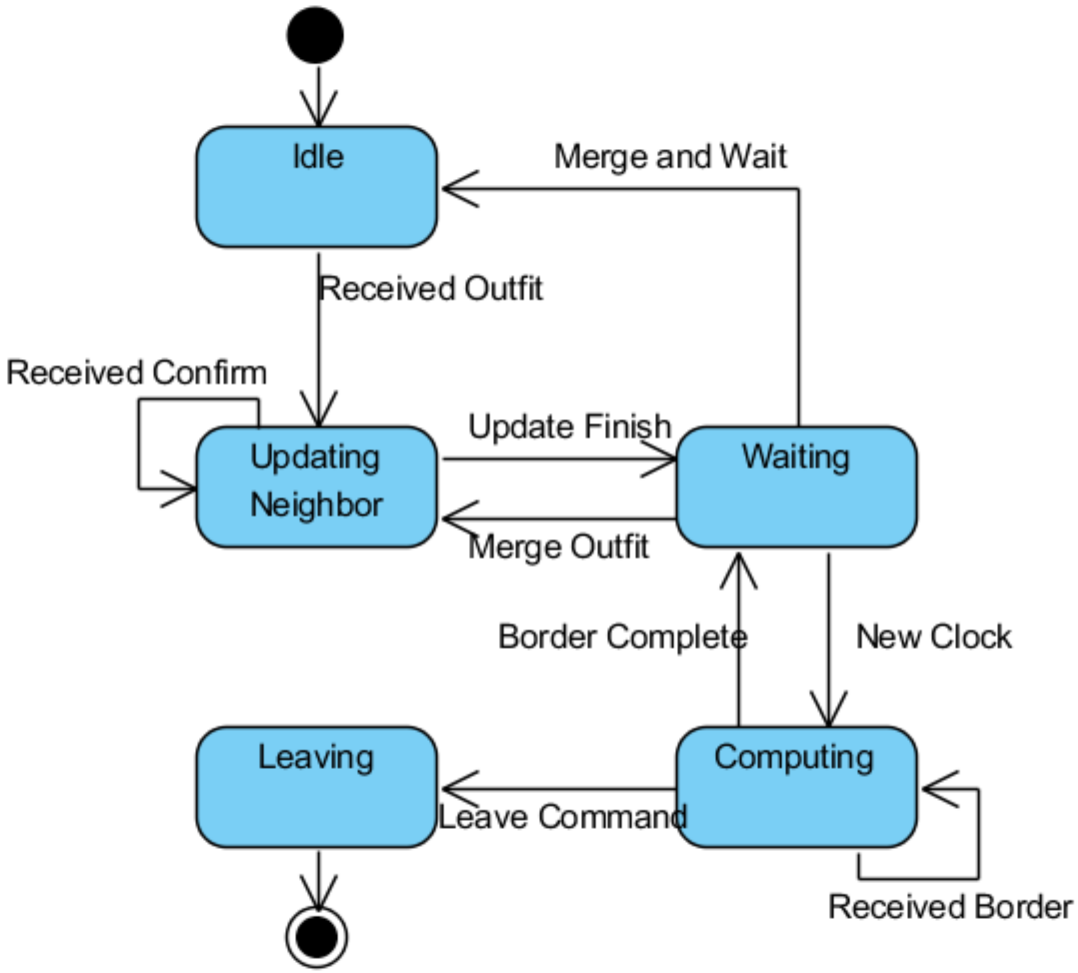
- State machine



Work Cycle

- Server
  - Cycle start
  - Synchronization
  - Wait for results & Handle missing
  - Merge & Refresh
  - Respond to requests(join, leave)
  - Cycle end

Client



Idle
Merge and Wait
Received Outfit
Received Confirm
Updating Neighbor
Update Finish
Waiting
Merge Outfit
Border Complete
New Clock
Leaving
Computing
Leave Command
Received Border

Work Cycle (cont.)

- Client
  - Send joining application to server
  - wait for accepting
  - Cycle start
  - Respond to server’s request of sibling change, replacement or new sibling
  - Synchronization
  - Compute
  - Compress if needed & Send
  - Back up if necessary
  - Send leaving application if necessary
  - Cycle end

Neighbor Updating

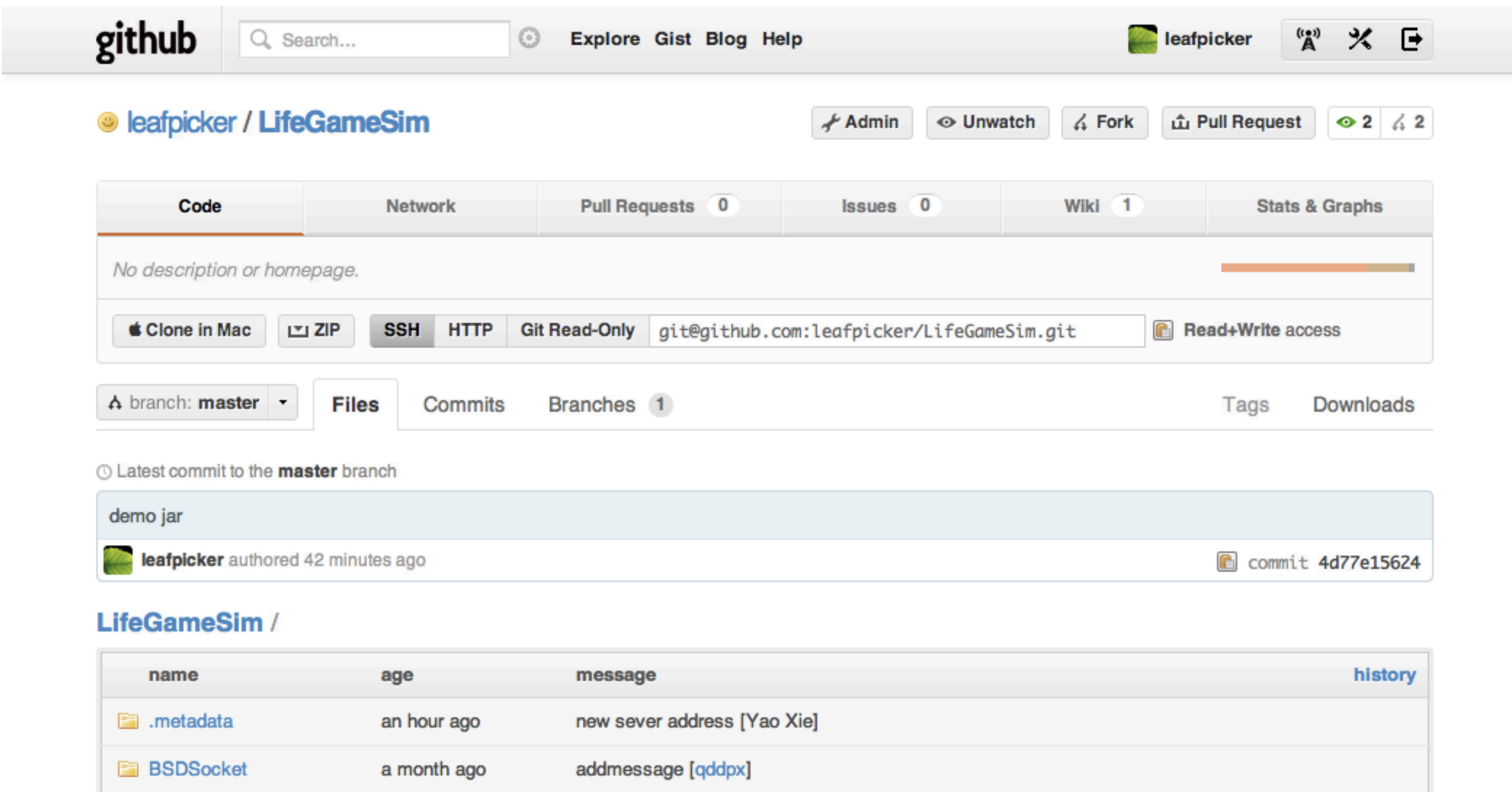
- Every node has up to 12 neighbors
- Send message to notice all neighbors

1	2	3	4
12			5
11			6
10	9	8	7

Message Queue

- Java NIO
- Multi-thread
  - Monitoring new connection
  - Monitoring new message and push to a queue with thread protection

Github Management



Performance Testing

Ensure the system will perform well and be reliable:

a) Under high user load
b) With a large dataset
c) Over an extended period time
d) As the load/dataset increases

Test Objectives

- With the increase of clients, we want to observe the updates(cycles) per second
- The longest computing time in each round
- The average computing time of each client in each round
- The network flow (including sending message and receiving message)

Test Strategy

- Append incoming clients to a pending list
- Add a new client per 20 cycles as a new round
- cycles / second = 20 * 1000 / (endTime – startTime)
- Each round:
  - Weakest-link principle (Cannikin Law)
  - compared with the longest computing time.
  - Monitor the sender and receiver and record the size of each package it send or receive
  - Total network flow = ∑ sender + ∑ receiver

Cannikin Law

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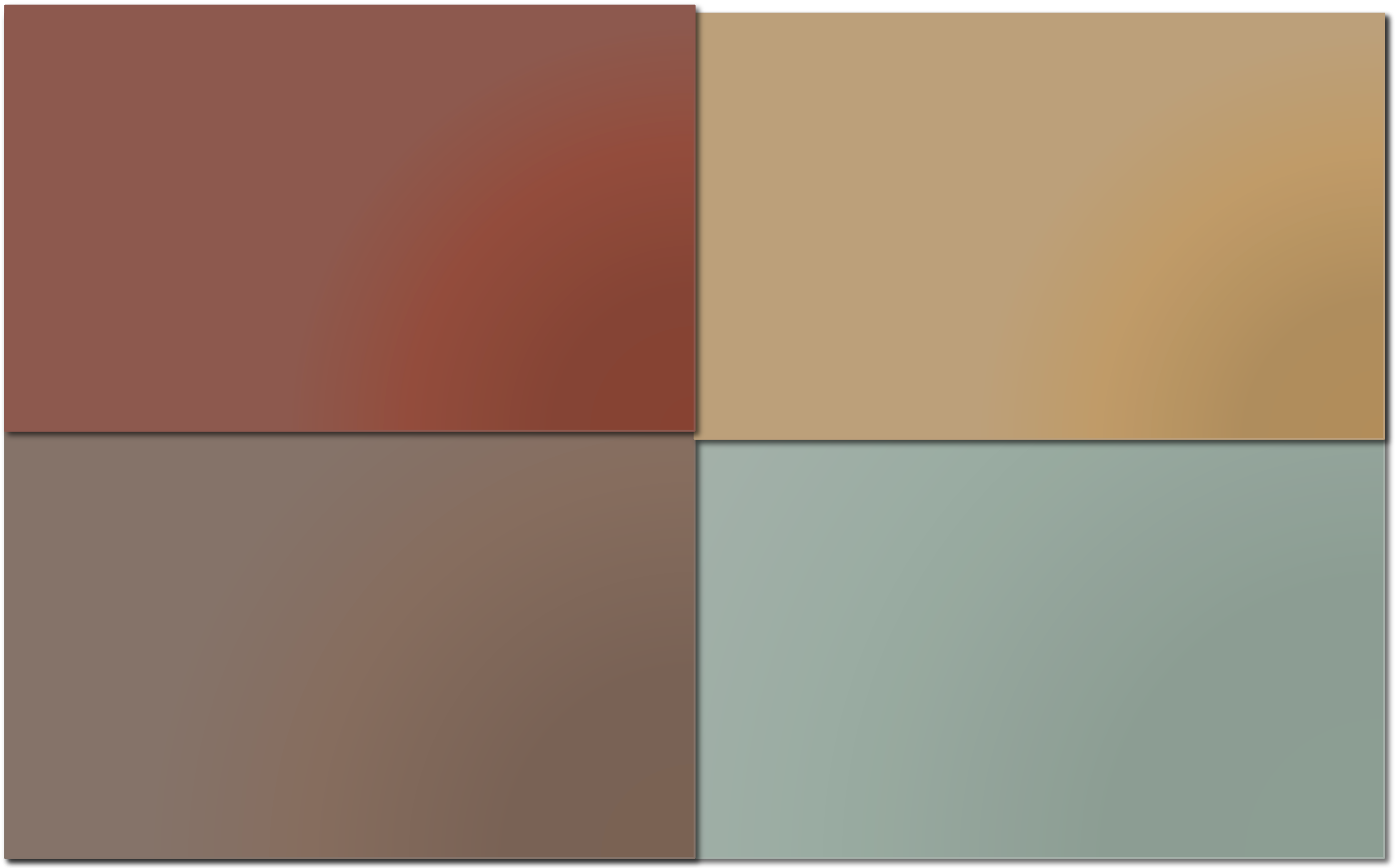
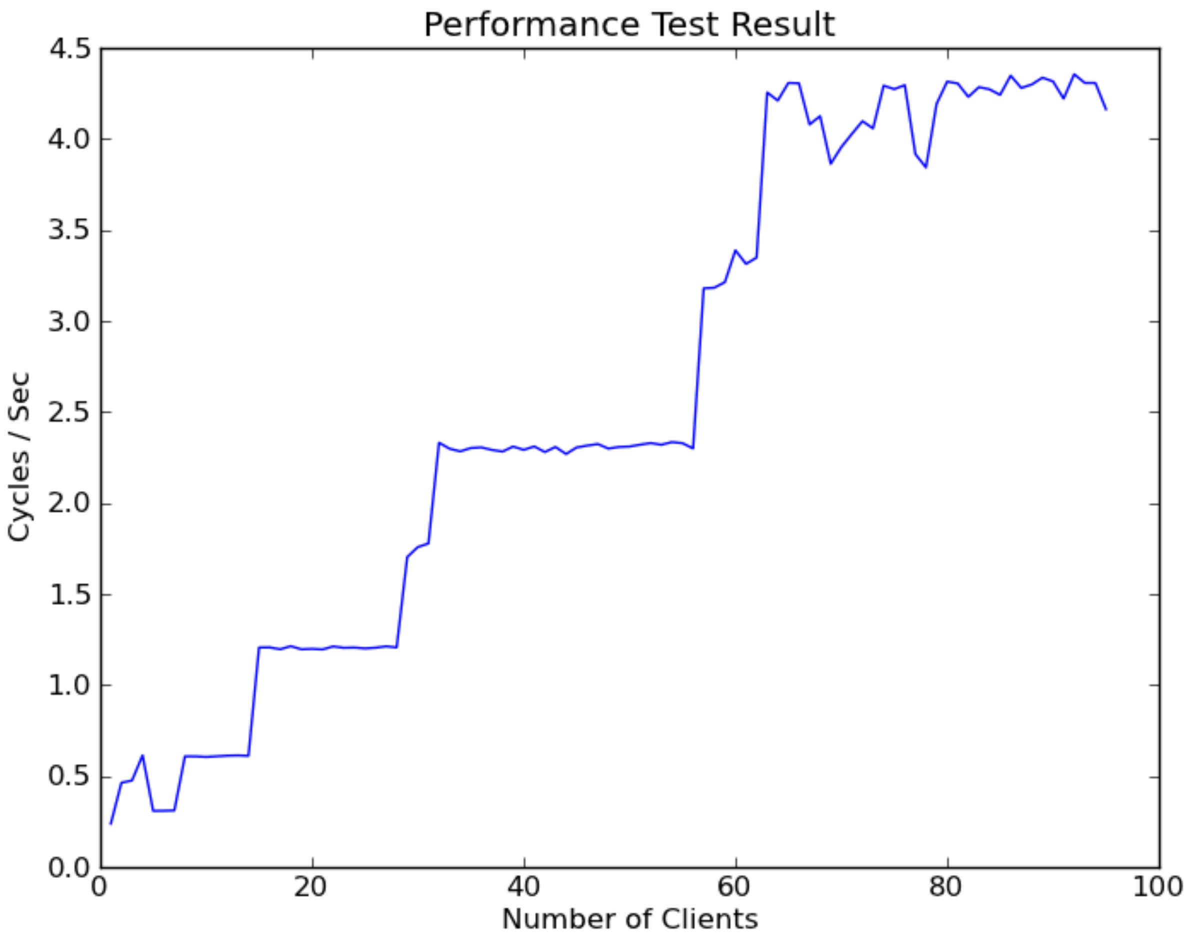
Cannikin Law

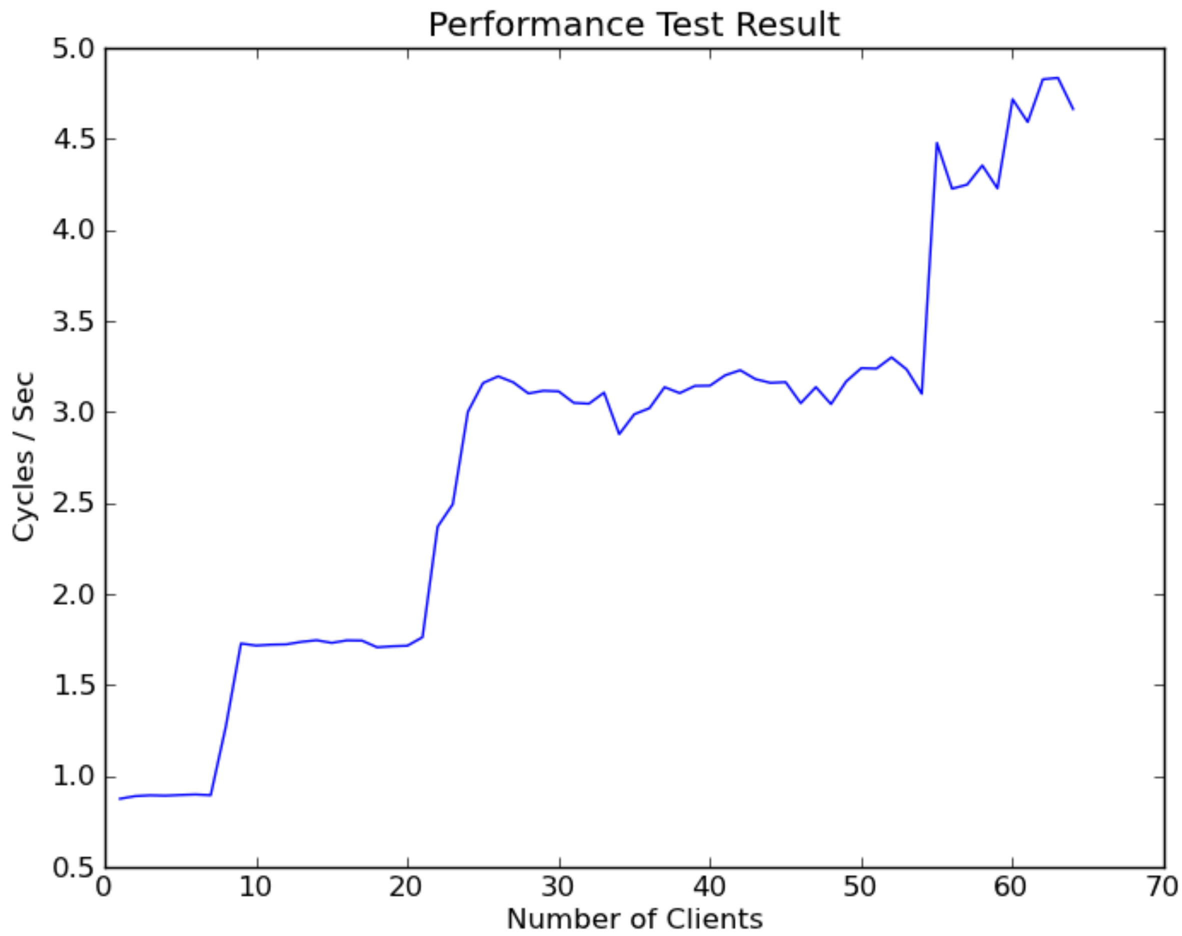


Sample Run 1



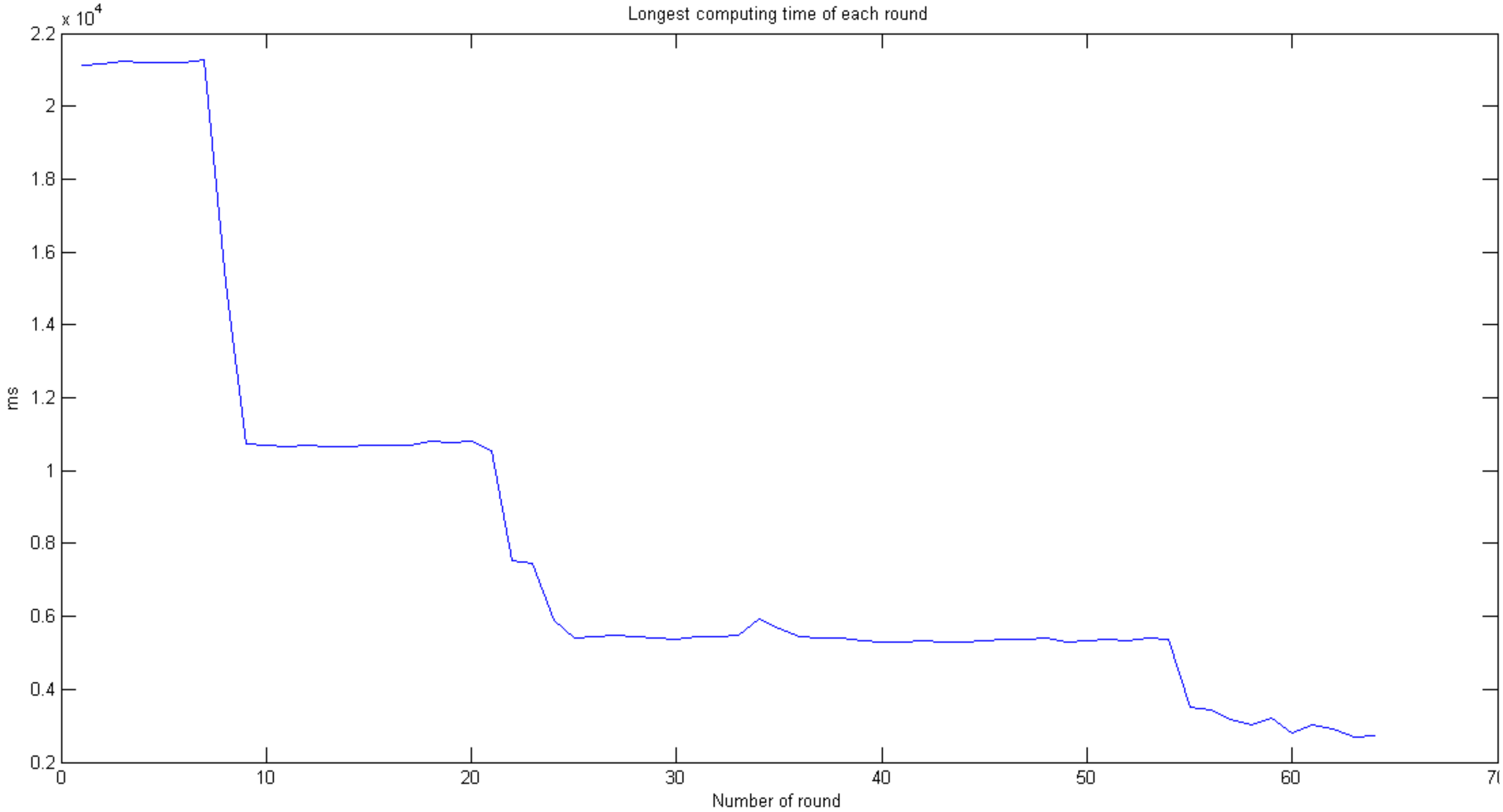
Performance Test Result
Cycles / Sec
Number of Clients
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
0
20
40
60
80
100

Sample Run 2

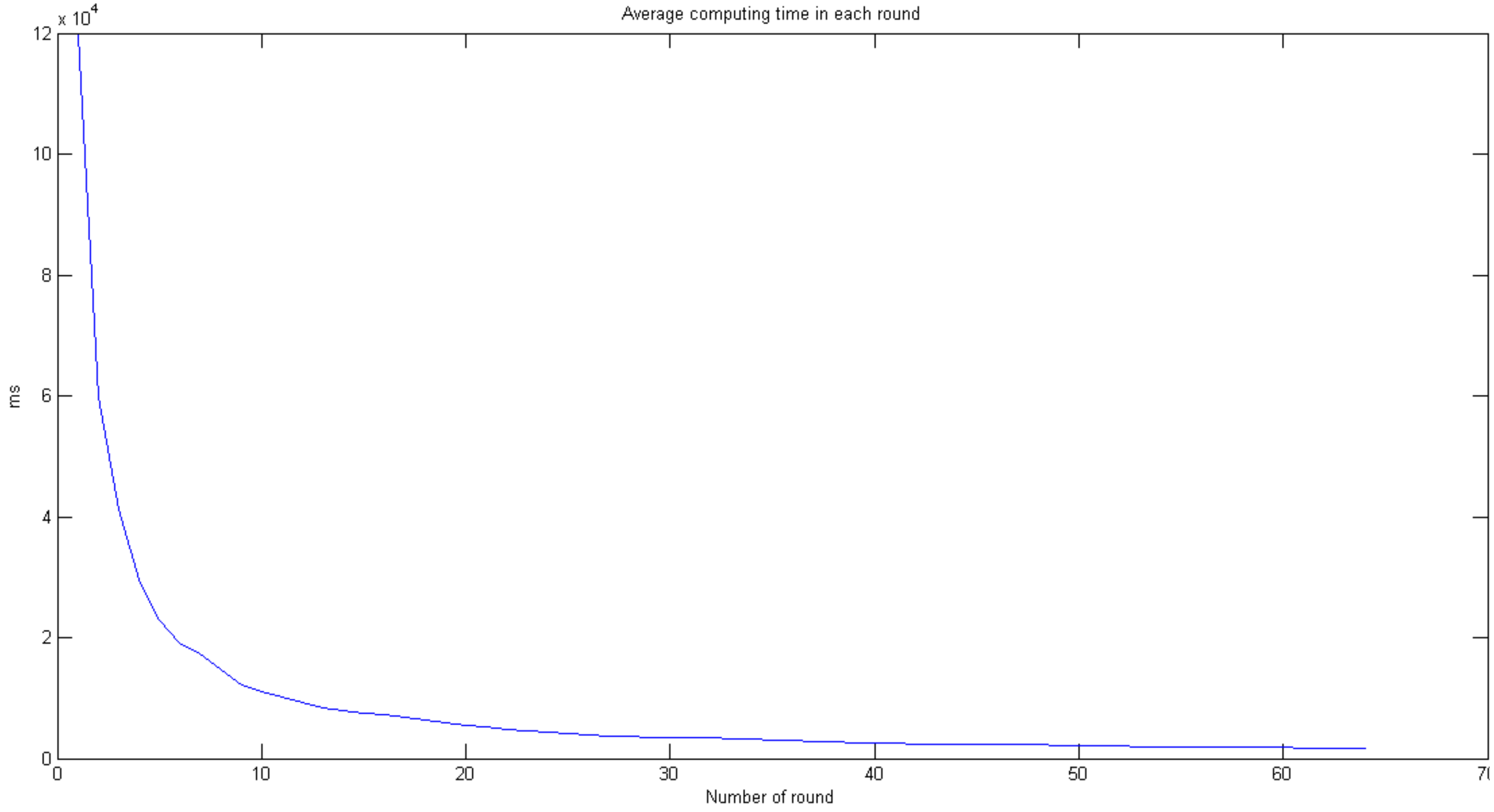


Performance Test Result
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
Cycles / Sec
0
10
20
30
40
50
60
70
Number of Clients

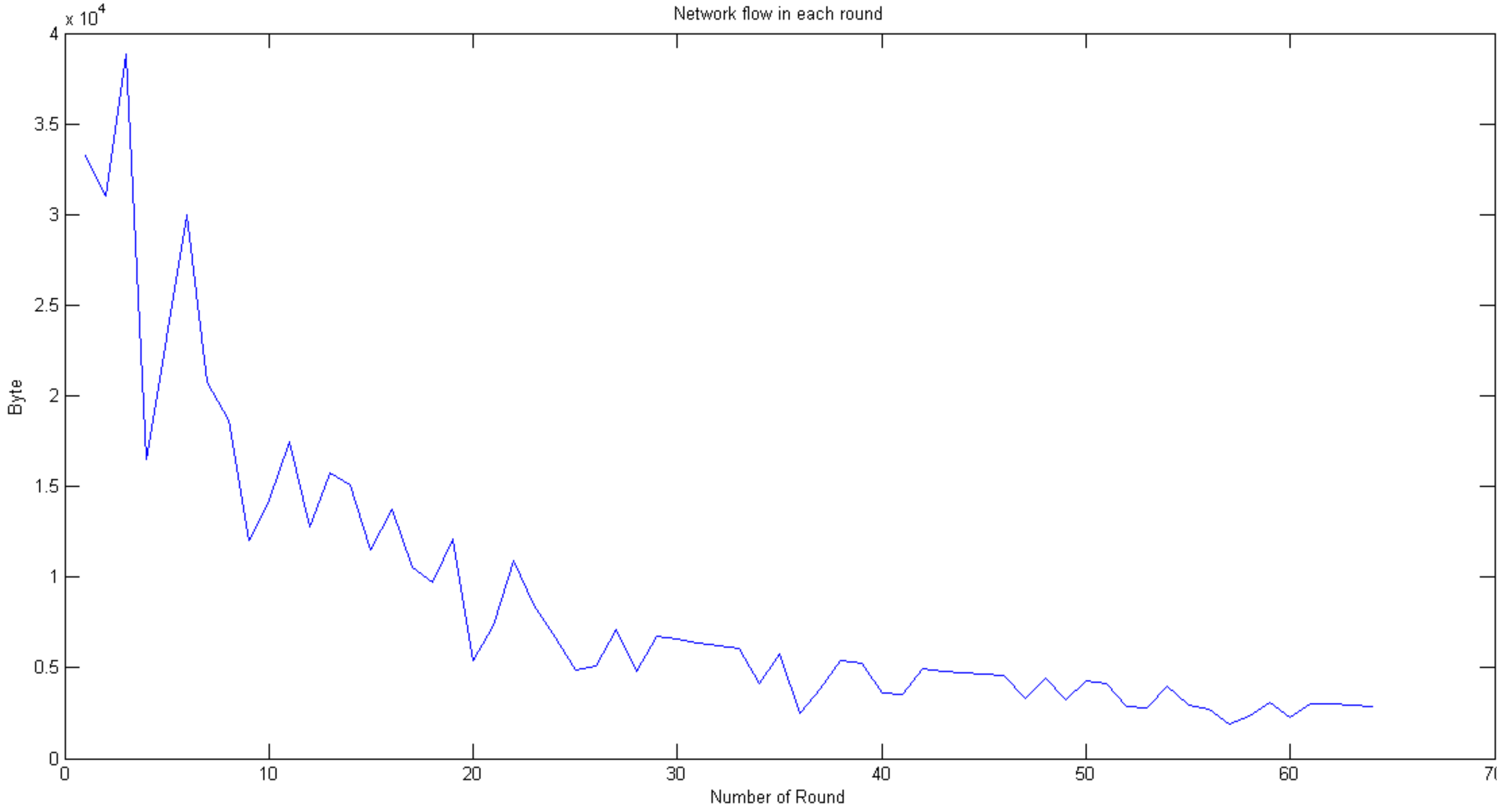
Longest Time



Average Time



Network Bandwidth



Conclusion

- The system can support dynamically adding and deleting computing nodes.
- It can support over 100,000,000 cells and 10,000,000 lives.
- With 100,000,000 cells, the system finishes about 4.5 cycles / sec, better than our expectation.

Questions?