High Fidelity Simulation of Distributed Applications

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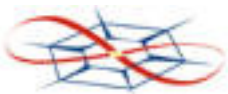
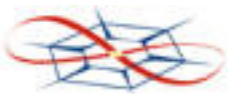


Outline

- Motivation
- Related Work
- Design of Simulation Environment
- Implementation
- Testing
  - Token Ring
  - Bully Algorithm
- Conclusions & Future Work

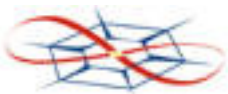
Motivation

- Distributed Applications
  - Debugging/Testing
  - Difficult to Control
  - Random context switches
    - Reproducibility
- Simulation
  - Building
  - Debugging/Testing
  - Consistent Application code



Related Work

- KU PNNI Simulator
  - Developed at KU
- MONARC Distributed System Simulation
  - Developed at Caltech
  - CERN (Particle physics lab)

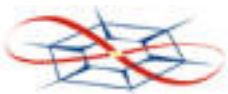


KU PNNI Simulator

- Describe/test/instrument PNNI
- Test PNNI Performance
- Reactor
- Scheduling
  - Virtual Time
- Real ATM switch software

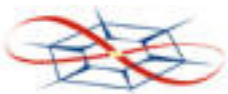
KU PNNI Simulator

- Disadvantages
  - Generic Application Simulation
  - Reproducibility of execution sequence
  - Network Modeling



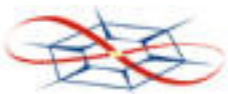
MONARC Distributed System Simulation

- Distributed Computing
  - Physics data processing
- Process oriented
- Java Multi-threading
- Network Model
  - LAN/WAN



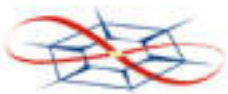
MONARC Distributed System Simulation

- Disadvantages
  - Generic Application Simulation
  - Reproducibility of execution sequence



Design

- Single Process
  - Thread per node
  - BThreads
    - User-level threads
    - One kernel thread
  - BERT Reactor
- Virtual Timeline
  - Timing
  - Network Delays
- Network Models

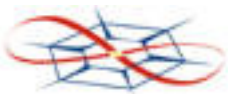


Classes

- *Application*
  - Base class
  - Simulation information
- *SimComm*
  - Communication
- *Network*
  - Network delay
- *SetUp*
- *SignalThreads*

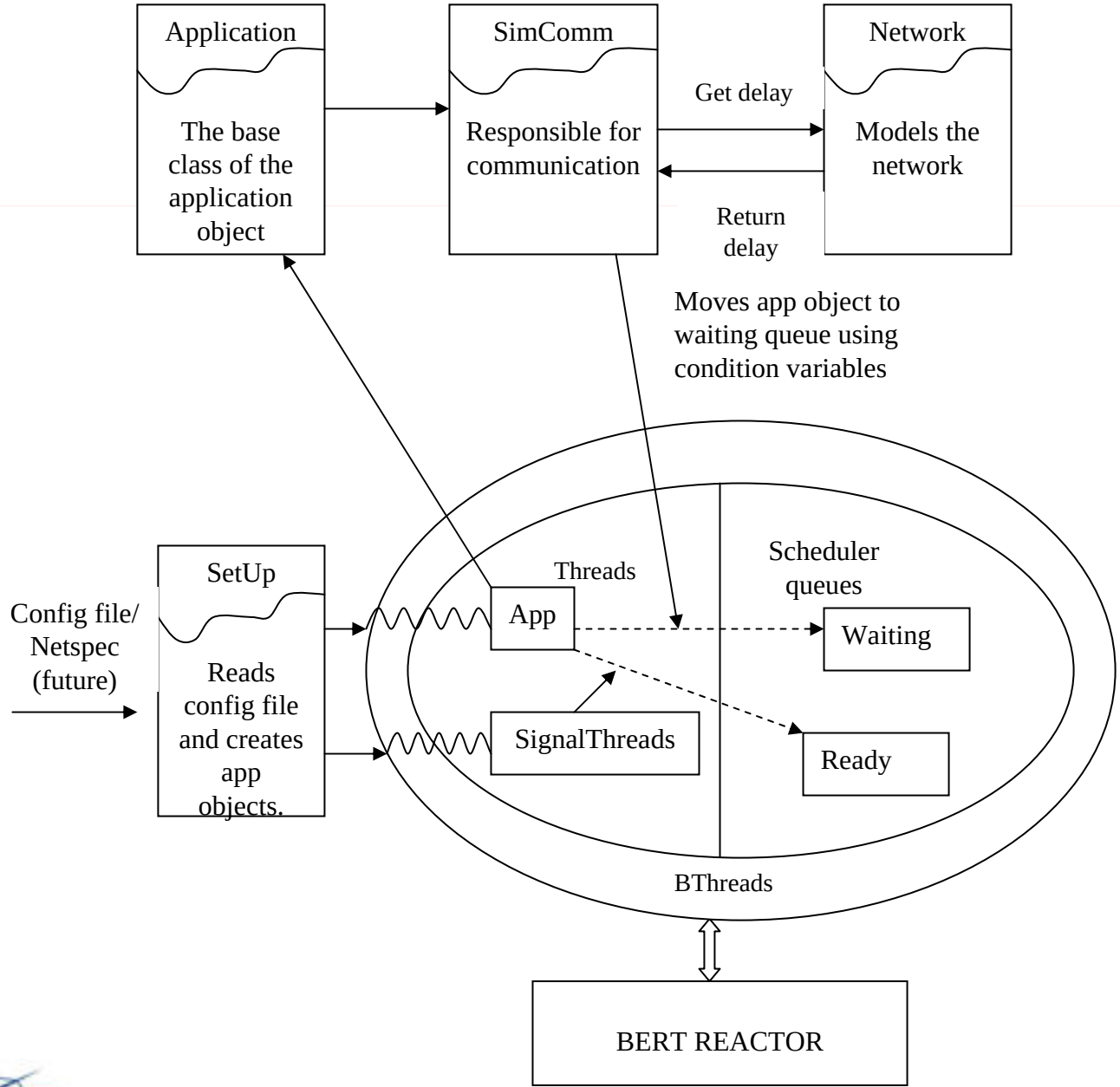
Implementation

- Configuration file
- *SetUp*
- Scheduler
  - Enqueue
    - Virtual Time
  - Dequeue
    - Head



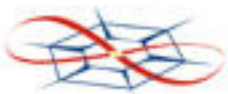
Implementation

- *SimComm*
  - Queues
  - Blocking I/O
  - Timestamp
    - *Network*
  - Receive message
    - Virtual Time > Message TS
    - Wait on condition variable
- *SignalThreads*
  - Increases Virtual Time
  - Signal condition variable


Application
The base class of the application object
SimComm
Responsible for communication
Get delay
Return delay
Network
Models the network
Moves app object to waiting queue using condition variables
SetUp
Reads config file and creates app objects.
Config file/ Netspec (future)
Threads
App
SignalThreads
Scheduler queues
Waiting
Ready
BThreads
BERT REACTOR

Application

- Simulated Mode
  - Virtual time
  - State
  - Wrapper functions for *SimComm*
  - Global instance
- Distributed Mode
  - Wrapper functions for *SimComm*



SimComm

- Simulated Mode
  - Communication
  - Queues
    - Uni-directional
    - 2 per process pair
    - Array
    - Connection descriptor – Array index
- Distributed Mode
  - Socket API wrapper
  - Connection descriptor = socket

SimComm Queue Allocation

- Queue state
  - INVALID, VALID, CLOSED
  - Allocated in pairs ((0,1), (2,3) ,(4,5),…)
  - Table of allocated queues
  - Connection descriptor: Write Queue
  - 1’s compliment: Read Queue
- Example A⟷B A=0, B=1

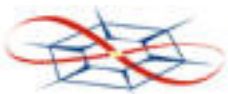
  0:A→B 1:B→A

Communication

```
int getConnection(struct sockaddr_in *my_ID,
                  struct sockaddr_in * peer_ID );

int Send(int ID ,void ** data ,int size );

int Recv(int ID ,void ** data ,int size );

int Close(int ID);
```

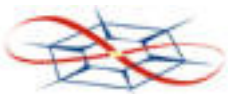
SignalThreads

- Inherits *Application*
- Array of application object pointers
- Sorts array by virtual time
  - Resembles ready queue
- First Blocked object
  - Increases virtual time
  - Signals condition variable



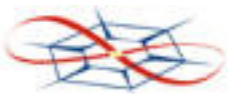
Testing

- Token Ring Network
  - Simulated mode
  - Distributed mode
- Bully Algorithm
  - Simulated mode
  - Distributed mode



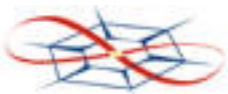
Token Ring Network

- Application object ⟶ Node
- Connects to neighbors
- Read from previous node
- Print Token
- Write to next node
- Loop token



Token Ring Design

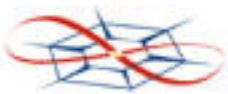
- ID,IP address, Port number, Starter
- IP address/Port number of neighbors
- Set up
  - Starter
    1. Next node
    2. Previous node
  - Others
    1. Previous node
    2. Next node



Configuration file

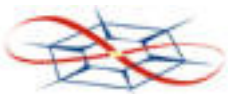
Field Name	Start Position	End Position
Node ID	1	4
Next node pointer	5	8
Previous node pointer	9	12
IP address	13	31
Port number	32	36

```
ID0100050002diannao.ittc.ku.edu10001
ID0200010003diannao.ittc.ku.edu10002
ID0300020004diannao.ittc.ku.edu10003
ID0400030005diannao.ittc.ku.edu10004
ID0500040001diannao.ittc.ku.edu10005
```



Distributed mode

- User
  - Path to configuration file
  - Number of loops
  - ID of node
- Application run in main thread
- ID01 starter
- Run 5 instances

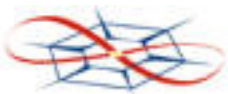


Distributed mode - Output

```
diannao [205] % SetUp config.txt 2 ID01
Machine ID ID01
LOOP COUNT 1
Token: TOKEN
Machine ID ID01
LOOP COUNT 2
Token: TOKEN
diannao [10] % SetUp config.txt 2 ID02
Machine ID ID02
LOOP COUNT 1
Token: TOKEN
Machine ID ID02
LOOP COUNT 2
Token: TOKEN
```

Output (Cont.)

```
diannao [9] % SetUp config.txt 2 ID03
Machine ID ID03
LOOP COUNT 1
Token: TOKEN
Machine ID ID03
LOOP COUNT 2
Token: TOKEN
diannao [9] % SetUp config.txt 2 ID04
Machine ID ID04
LOOP COUNT 1
Token: TOKEN
Machine ID ID04
LOOP COUNT 2
Token: TOKEN
```

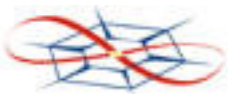


Output (Cont.)

```
diannao [9] % SetUp config.txt 2 ID05
Machine ID ID05
LOOP COUNT 1
Token: TOKEN
Machine ID ID05
LOOP COUNT 2
Token: TOKEN
```

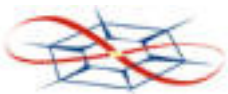
Simulated Mode

- User
  - Path to configuration file
  - Number of loops
- ID01 starter
- *SetUp* creates 5 instances
- Application run in user-level threads
- *SignalThreads*



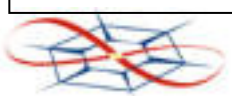
Simulated Mode -Output

```
diannao [2] % SetUp config.txt 2
Machine ID ID01
LOOP COUNT 1
Token: TOKEN
Machine ID ID02
LOOP COUNT 1
Token: TOKEN
Machine ID ID03
LOOP COUNT 1
Token: TOKEN
Machine ID ID04
LOOP COUNT 1
Token: TOKEN
Machine ID ID05
LOOP COUNT 1
Token: TOKEN
```

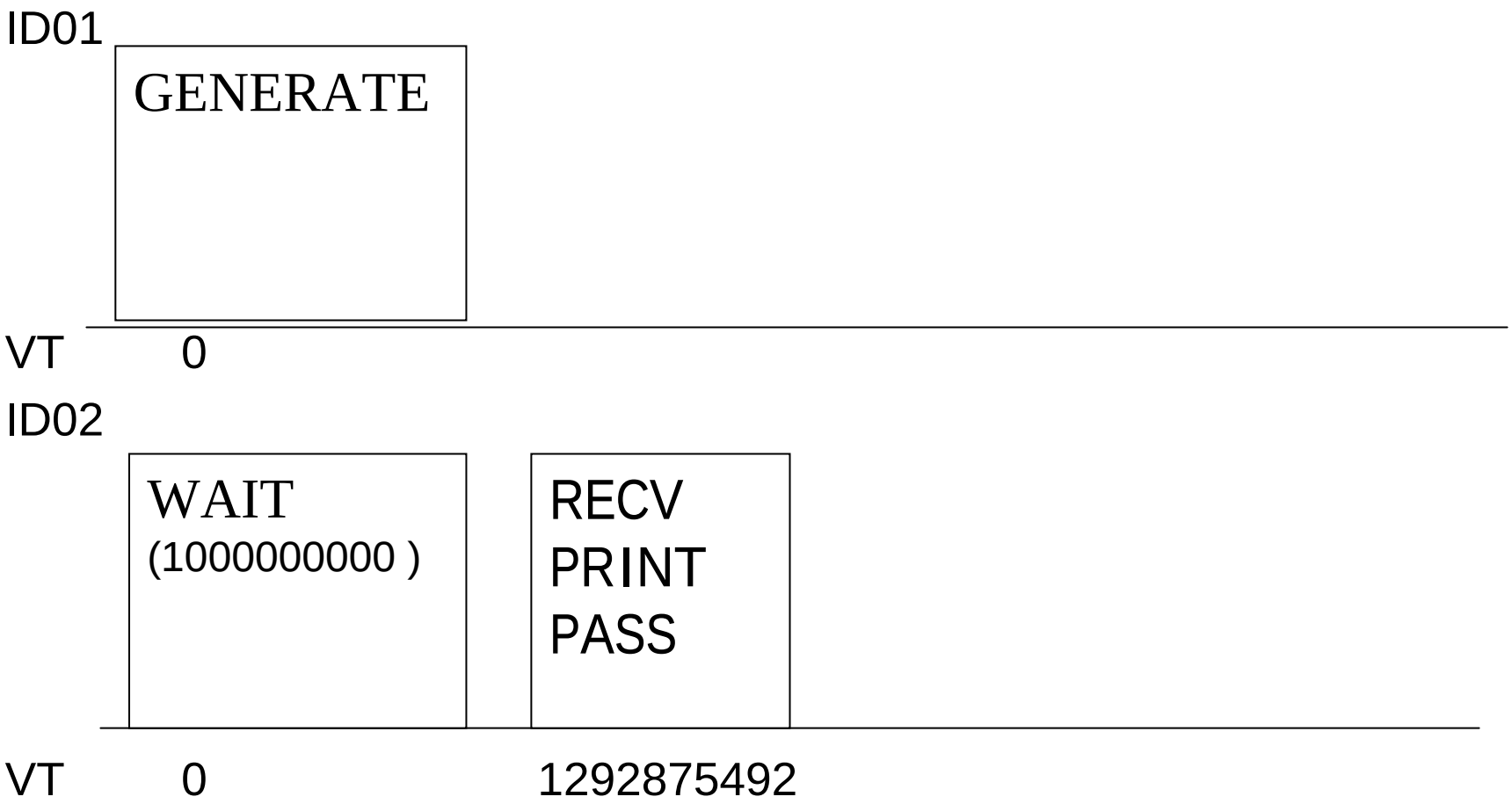


Output (Cont.)

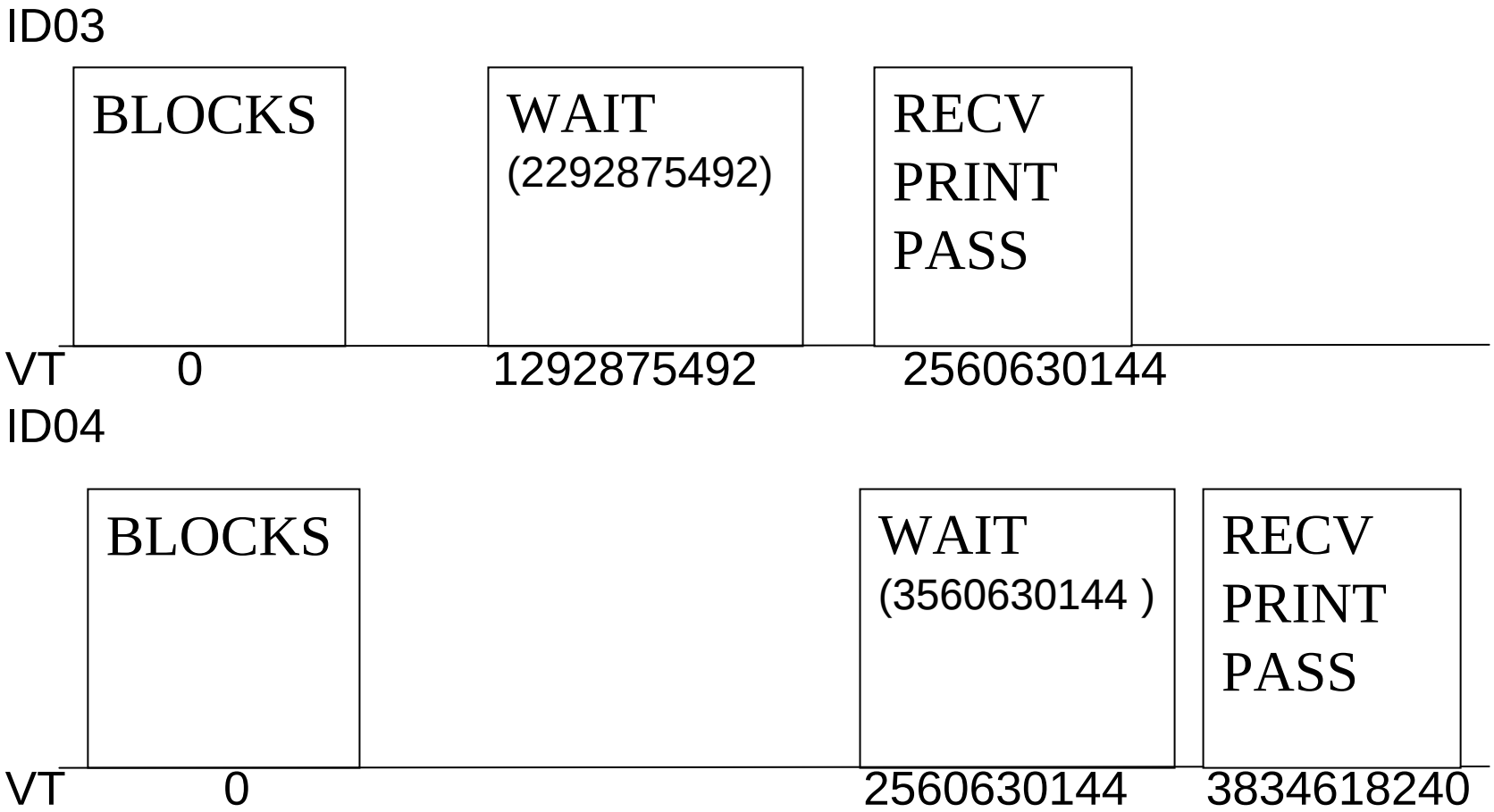
```
Machine ID ID01
LOOP COUNT 2
Token: TOKEN
Machine ID ID02
LOOP COUNT 2
Token: TOKEN
Machine ID ID03
LOOP COUNT 2
Token: TOKEN
Machine ID ID04
LOOP COUNT 2
Token: TOKEN
Machine ID ID05
LOOP COUNT 2
Token: TOKEN
```



Virtual Timeline

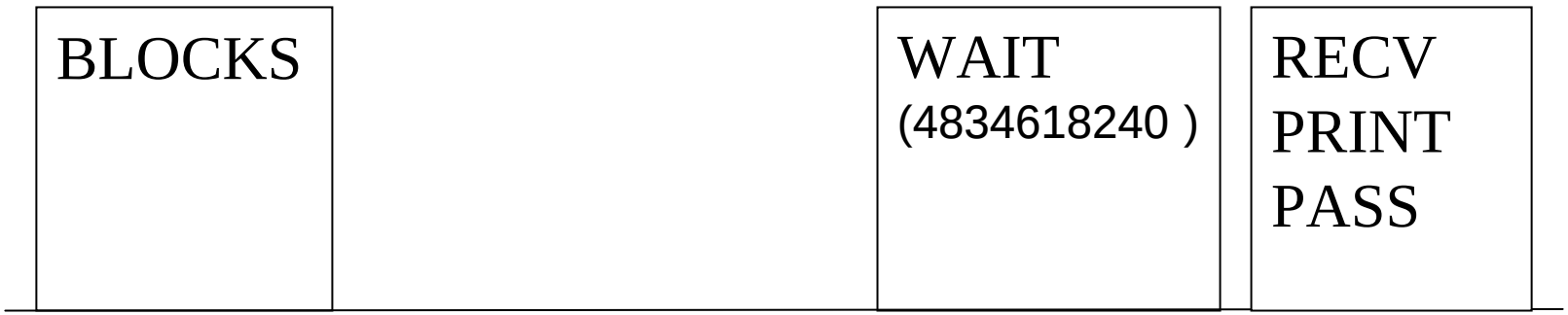


Virtual Timeline



Virtual Timeline

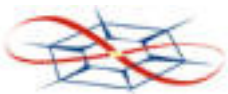
ID05



VT 0 3834618240 5095471568

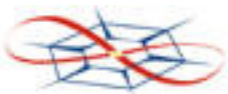
Bully Algorithm

- Application object ⟶ Node
- Elect Leader
- Send Election message to higher nodes
- Lose if receive acknowledgement
- Winner: Highest ID
- Better Test
  - Communication
  - Concurrency



Bully Algorithm Design

- ID,IP address, Port number
- IP address/Port number of all others
- Set up
  - Identify lower/higher nodes
  - Connect to all
- Receive election message from lower nodes
  - Send acknowledgement
- Send election message to higher nodes.
- Check for acknowledgement
- Win if no acknowledgement



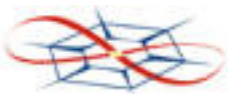
Configuration file

Field Name	Start Position	End Position
Node ID	1	4
IP address	5	23
Port number	24	28

```
0001diannao.ittc.ku.edu10001
0002diannao.ittc.ku.edu10002
0003diannao.ittc.ku.edu10003
0004diannao.ittc.ku.edu10004
0005diannao.ittc.ku.edu10005
0006diannao.ittc.ku.edu10006
0007diannao.ittc.ku.edu10007
0008diannao.ittc.ku.edu10008
0009diannao.ittc.ku.edu10009
0010diannao.ittc.ku.edu10010
```

Distributed mode

- User
  - Path to configuration file
  - ID of node
- Application run in main thread
- Run 10 instances

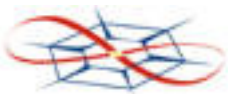


Distributed mode - Output

```
diannao [27] % SetUp config.txt 0001
diannao [27] % SetUp config.txt 0002
diannao [27] % SetUp config.txt 0003
diannao [27] % SetUp config.txt 0004
diannao [27] % SetUp config.txt 0005
diannao [27] % SetUp config.txt 0006
diannao [27] % SetUp config.txt 0007
diannao [27] % SetUp config.txt 0008
diannao [27] % SetUp config.txt 0009
diannao [3] % SetUp config.txt 0010
My ID is 0010. I have won the election.
```

Simulated Mode

- User
  - Path to configuration file
- *SetUp* creates 10 instances
- Application run in user-level threads
- *SignalThreads*

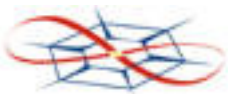


Simulated mode - Output

```
diannao [6] % SetUp config.txt
My ID is 0010. I have won the election.
```

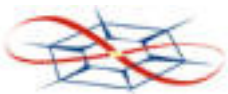
Conclusions

- Novel Approach
- User-level thread library
- Reactor
- Debugging
- Consistent Application code
  - C++ objects



Conclusions

- Communication
- Network models
- Virtual timeline
  - Sequence events
  - Message delivery delayed
- Token Ring
- Bully Algorithm



Future Work

- Reactor
  - Record debugging info
  - Replay execution
- Network Model
  - Constant delay
  - Dynamic
  - Message size, Bandwidth, source, destination

Thank You