MONASH University

GROUP ASSIGNMENT COVER SHEET

Student ID Number	Surname	Given Names
32179081	Hermawan	Editha Karina
31316115	Wijaya	Lionie

* Please include the names of all other group members.

Unit name and code	FIT3143 - Parallel Computing	
Title of assignment	Design and Implementation of a Distributed Wireless Sensor Network Simulator to Detect Underwater Earthquakes	
Lecturer/tutor	Dr. Vishnu Monn	
Tutorial day and time	Wednesday 2pm	**Campus** Malaysia
Is this an authorised group assignment?	**Yes**	**No**
Has any part of this assignment been previously submitted as part of another unit/course?	**Yes**	**No**
Due Date 18/10/22		**Date submitted** 18/10/22

All work must be submitted by the due date. If an extension of work is granted this must be specified with the signature of the lecturer/tutor.

Extension granted until (date) ..... **Signature of lecturer/tutor** .....

Please note that it is your responsibility to retain copies of your assessments.

Intentional plagiarism or collusion amounts to cheating under Part 7 of the Monash University (Council) Regulations

Plagiarism: Plagiarism means taking and using another person's ideas or manner of expressing them and passing them off as one's own. For example, by failing to give appropriate acknowledgement. The material used can be from any source (staff, students or the internet, published and unpublished works).

Collusion: Collusion means unauthorised collaboration with another person on assessable written, oral or practical work and includes paying another person to complete all or part of the work.

Where there are reasonable grounds for believing that intentional plagiarism or collusion has occurred, this will be reported to the Associate Dean (Education) or delegate, who may disallow the work concerned by prohibiting assessment or refer the matter to the Faculty Discipline Panel for a hearing.

MONASH University

Student Statement:

- I have read the university's Student Academic Integrity Policy and Procedures.
- I understand the consequences of engaging in plagiarism and collusion as described in Part 7 of the Monash University (Council) Regulations http://adm.monash.edu/legal/legislation/statutes
- I have taken proper care to safeguard this work and made all reasonable efforts to ensure it could not be copied.
- No part of this assignment has been previously submitted as part of another unit/course.
- I acknowledge and agree that the assessor of this assignment may for the purposes of assessment, reproduce the assignment and:
  i. provide to another member of faculty and any external marker; and/or
  ii. submit it to a text matching software; and/or
  iii. submit it to a text matching software which may then retain a copy of the assignment on its database for the purpose of future plagiarism checking.
- I certify that I have not plagiarised the work of others or participated in unauthorised collaboration when preparing this assignment.

Signature .....Editha, Lionie..... *Date.....17/10/22.....*

* delete (iii) if not applicable

Signature _____Editha_____Date:_____17/10/22_____ Signature _____Date:_____

Signature _____Lionie_____Date:_____17/10/22_____ Signature _____Date:_____

Privacy Statement

The information on this form is collected for the primary purpose of assessing your assignment and ensuring the academic integrity requirements of the University are met. Other purposes of collection include recording your plagiarism and collusion declaration, attending to course and administrative matters and statistical analyses. If you choose not to complete all the questions on this form it may not be possible for Monash University to assess your assignment. You have a right to access personal information that Monash University holds about you, subject to any exceptions in relevant legislation. If you wish to seek access to your personal information or inquire about the handling of your personal information, please contact the University Privacy Officer: privacyofficer@adm.monash.edu.au

MONASH University

FIT3143 Semester 2, 2022
Assignment 2 - Report
Design and Implementation of a Distributed Wireless Sensor Network Simulator to Detect Underwater Earthquakes

Team Name (or Number): __Team 1 Lab 6_____

Student email address	Student First Name	Student Last Name	Contribution %	Contribution details*
eher0010@student.monash.edu	Editha Karina	Hermawan	50%	Task 1 and Task 3: seafloor nodes MPI processes and threads, send-receive mechanism including data packing between nodes and between nodes and base station
lwij0012@student.monash.edu	Lionie	Wijaya	50%	Task 2: balloon array and thread; Task 3: base station MPI process and thread, logging, and termination;

**Your contribution details include the report, code, or both.*

Note: Please refer to Assignment specifications, FAQ and marking guidelines for details to be included in the following sections of this report.

Include the word count here (for Sections A to C): _1579 words_

MONASH University

How to compile and run our program

```
To compile:
     make all
     or
     mpicc wsn.c utils.c alert.c balloon.c node.c -lm -lpthread -o wsn
   To run via command line argument in VM:
     version 1 - fixed number of iterations
     mpirun --oversubscribe -np [number of process] wsn [grid row] [grid column]
[difference in magnitude threshold] [difference in distance threshold] [number of
iterations]
     version 2 - programs stops during runtime after user set a sentinel value of 2 in
sentinel.txt
     mpirun --oversubscribe -np [number of process] wsn [grid row] [grid column]
[difference in magnitude threshold] [difference in distance threshold]
   To run via CAAS (only fixed number of iterations is allowed):
     srun wsn [grid row] [grid column] [difference in magnitude threshold] [difference in
distance threshold] [number of iterations]
```

```
fit3143-student@fit3143:~/Documents/As2$ make all
mpicc wsn.c utils.c alert.c balloon.c node.c -lm -lpthread -o wsn
fit3143-student@fit3143:~/Documents/As2$ mpirun --oversubscribe -np 13 wsn 4 3 1 1500 5
Dimension 4x3 | Difference in magnitude threshold 1.000000 | Difference in distance threshold 1500.000000 | Iterations 5
--------- Starting Earthquake Detection Simulation
********* Currently in iteration 1 ...
********* Currently in iteration 2 ...
********* Currently in iteration 3 ...
********* Currently in iteration 4 ...
********* Currently in iteration 5 ...
--------- Earthquake Detection Simulation Completed
fit3143-student@fit3143:~/Documents/As2$ mpirun --oversubscribe -np 13 wsn 4 3 1 1500
Dimension 4x3 | Difference in magnitude threshold 1.000000 | Difference in distance threshold 1500.000000 | Iterations is based on sentinel value set
during runtime, termination only after user save a sentinel value of 2 in sentinel.txt file
--------- Starting Earthquake Detection Simulation
********* Currently in iteration 1 ... sentinel.txt has no sentinel value of 2 set yet
********* Currently in iteration 2 ... sentinel.txt has no sentinel value of 2 set yet
********* Currently in iteration 3 ... sentinel.txt has no sentinel value of 2 set yet
********* Currently in iteration 4 ... sentinel.txt has no sentinel value of 2 set yet
User has set a sentinel value to terminate program in sentinel.txt
--------- Earthquake Detection Simulation Completed
```

A. Methodology

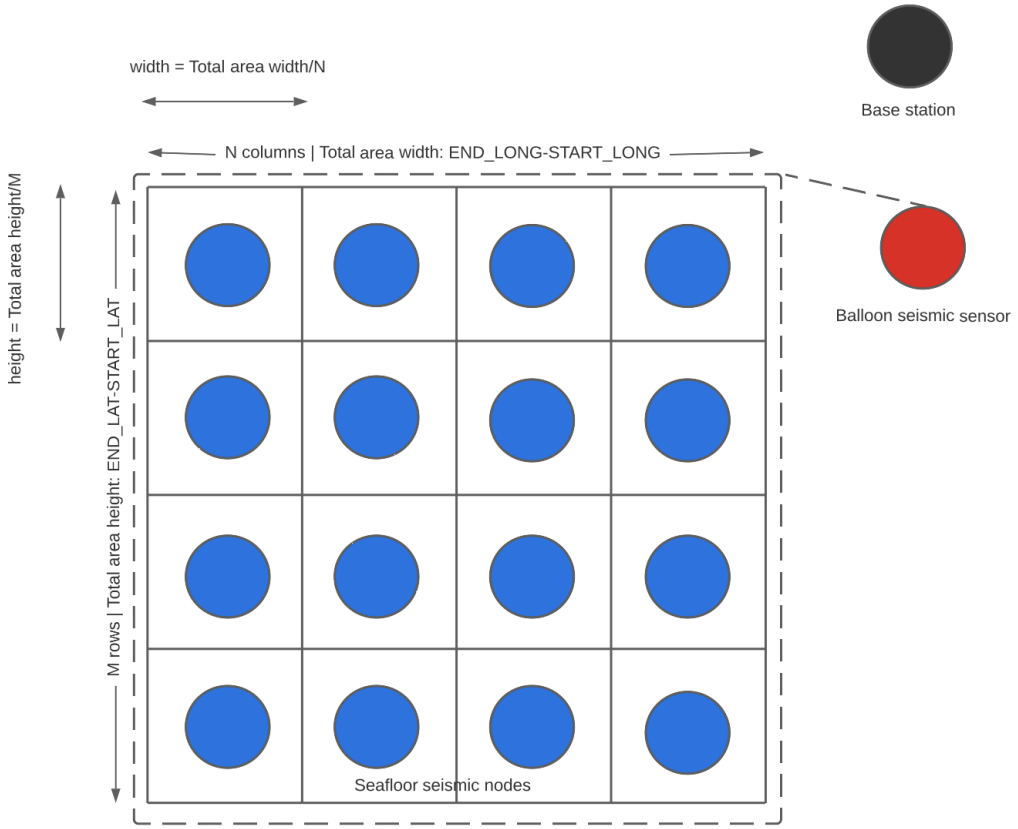


Figure 1. Grid illustration of Wireless Sensor Network implementation

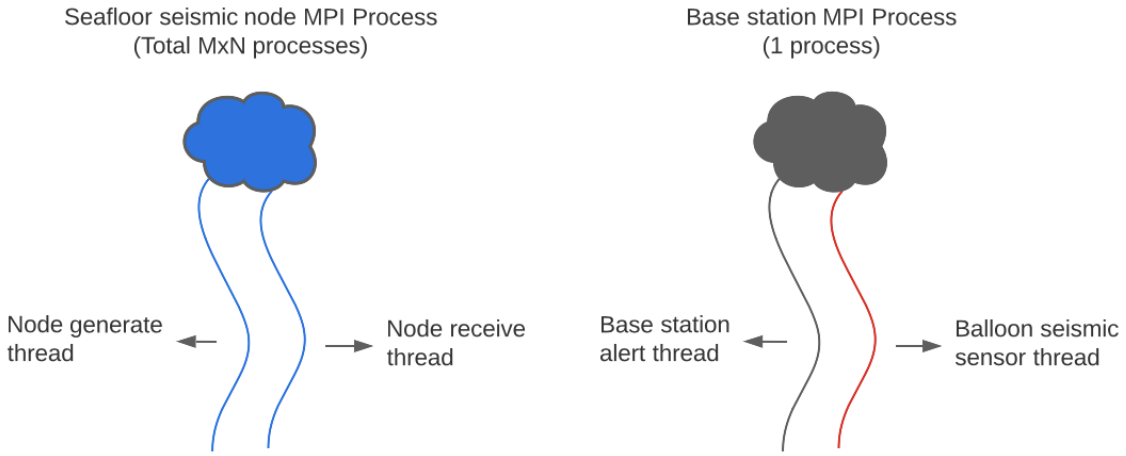


Figure 2. MPI processes and POSIX threads representing seafloor seismic nodes, balloon seismic sensor, and base station

To simulate a Wireless Sensor Network following the illustration in figure 1, MPI and POSIX threads are used as shown in figure 2. One MPI rank broadcasts user input in command line arguments to all other ranks. MPI processes are split, one for base station and rest for seafloor nodes and each process will create threads to fulfil requirements

(refer to section 1, 2, and 3). Adjustments and blocking using MPI_Barrier are done in the overall implementation structure to ensure correct simulation. First, MPI processes must receive broadcasted input before continuing. Then, both balloon and alert thread must be created before seafloor node threads as they depend on both of them. Afterwards, ensure all threads have been spawned before simulation starts - program runs without this, however there is a tendency of having no logs for the first few iterations as base station's MPI process possibly starts iteration early and by the time alert logs the iteration is already updated. Finally, ensure all MPI processes join and terminate their thread correctly before terminating all processes.

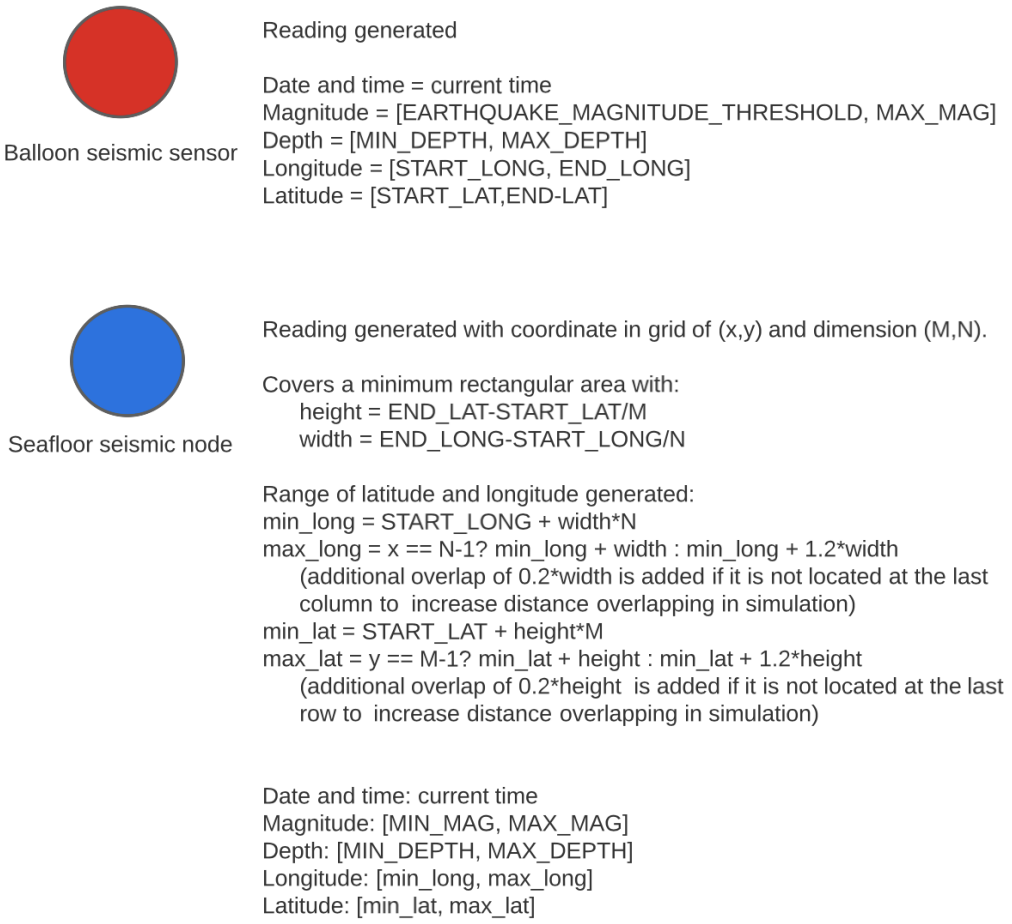


Figure 3. Reading information generated by balloon and seafloor seismic nodes

1. Seafloor Seismic Node

```
Initialize new MPI communication group for sea floor nodes using MPI_Comm_split
Initialize MPI virtual topology for ocean nodes (includes initializing the communicator, the coordinates of each node, and its neighbours)

if rank != p-1 then
    lock reading
    reading = generateNodeReading()
    unlock reading
    initialize generate thread with nodeGenerateThread function and argsGenerate
    initialize receive thread with nodeReceiveThread function and argsReceive
    MPI_Recv into sentinel
    Clean up threads
end if
```

```
function nodeGenerateThread(args)
    data = cast args to GenerateThread pointer data type
    initialize mainComm, currCartcomm, nbrs[4], dims[2], coords[2], size, threshold_diff_magnitude, threshold_diff_distance, currRank, baseRank,
    packBufferRecv[size]
    initialize lock, timespec start and end, time_taken

    While data->sentinel != SENTINEL do
        clock_gettime into start

        mutex lock
        data->reading = generateNodeReading()
        mutex lock

        if data->reading->magnitude > magnitude threshold do
            for i=1 to 4 do
                if nbrs[i]>=0 do
                    MPI_Send currRank
                end if
            end for

            initialize compareResult[4], adjacentNodeBuffer[4], matchings, totalNeighbour

            for i = 1 to 4 do
                if nbrs[i]>=0 do
                    flag = false
                    MPI_Iprobe into flag
                    If flag is true do
                        MPI_Recv into packBufferRecv
                        neighbour = MPI_Unpack packBufferRecv in order: magnitude, latitude, longitude, depth, datetime, coordinates
                        comparison = compareTwoReadings(data,neighbour)
                        if comparison.matching is true then
                            matching += 1
                        end if
                        adjacentNodeBuffer[totalNeighbour] = copy(packBufferRecv)
                        totalNeighbour +=1
                    end for
            end for
```

```
        end if

        if matching >= 2 do
            packedData = MPI_Pack the following data in order: number of total neighbours, number of matchings, current node's data (magnitude,
            latitude, longitude, depth, datetime, and coordinates)
            for i=0 to totalNeighbour-1 do
                packedData = MPI_Pack neighbour node's data (magnitude, latitude, longitude, depth, datetime, coordinates)
            end for
            MPI_Send packedData to base station
        end if
    clock_gettime into end
    sleep(cycle node - (end - start))
end function

function nodeRecvThread(args)
    data = cast args to RecvThread datatype
    initialize currCartcomm, reading, coords[2], totalSize, sourceRank my_rank, packBuffer[totalSize]
    initialize MPI_Status status
    initialize MPI_Request request

    While data->sentinel != SENTINEL do
        initialize flag to false
        MPI_Iprobe into flag
        if flag is true do
            MPI_Recv into sourceRank
            packBuffer = MPI_Pack the following data in order: current node's data (magnitude, latitude, longitude, depth, datetime, and
            coordinates)
            MPI_Send(packBuffer)
        end if
    end while
end function
```

Figure 4. Seafloor seismic node implementation pseudocode

As seen in figure 1 and 2, a seafloor seismic node covers a portion of area covered by the balloon seismic sensor and is represented by an MPI process with two threads spawned. From figure 4, all nodes are included into one communicator group as part of a virtual topology cartesian mapping. Each node is assigned with a new rank for the new communicator group and stores their direct neighbours' ranks. Each node generates reading, requests for readings from its neighbour if generated magnitude exceeds predefined earthquake magnitude threshold, and alerts the base station if at least two neighbours have matching readings. As a neighbour of other adjacent nodes, it also waits and listens for requests to send their latest reading.

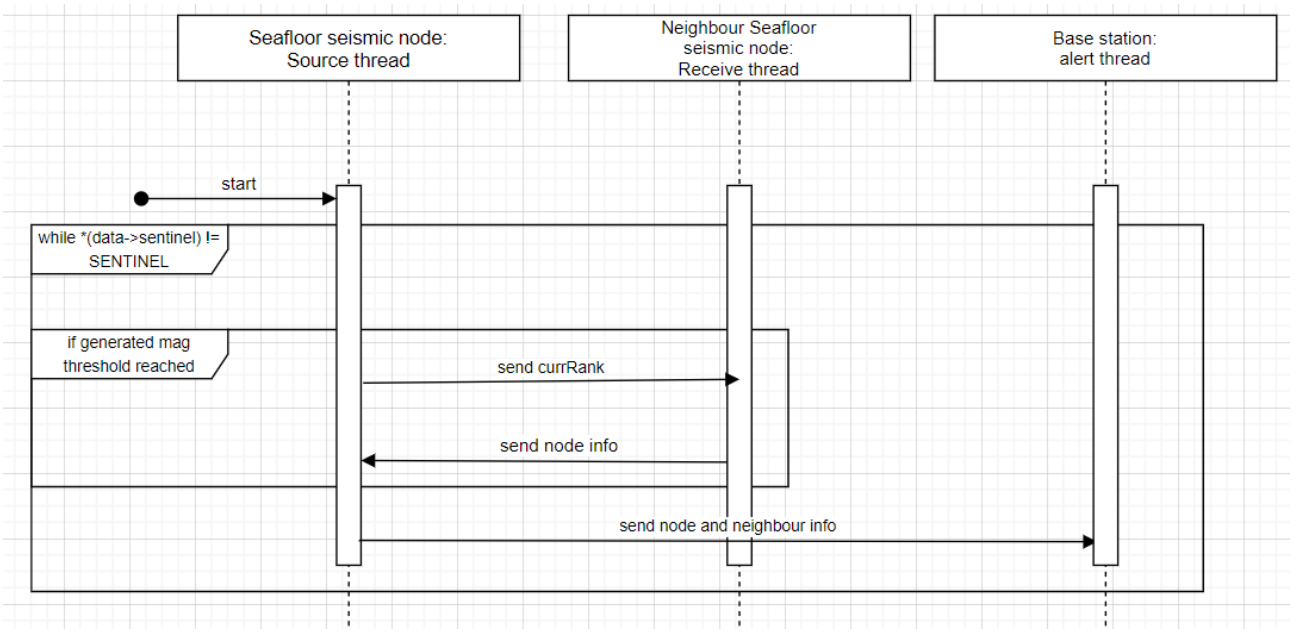


Figure 5. Seafloor seismic node generate and receive threads interaction

To support tasks mentioned, generate and receive threads are created. Details of threads and their interactions are shown in figure 5. Both threads run continuously until a termination message is received from the base station. For each time interval, generate node thread generates a reading based on figure 3 and checks whether it exceeds magnitude threshold value, if it does it sends an MPI message of its own rank to neighbour ranks. Receive node thread from the neighbour ranks, which continuously listen, receive it and send over their latest reading information back. Afterwards, the source generate node thread compares readings received to its latest reading, only if two or more matchings where the difference in magnitude and distance are under the threshold specified during runtime, then it alerts the base station by sending all required information needed to alert thread.

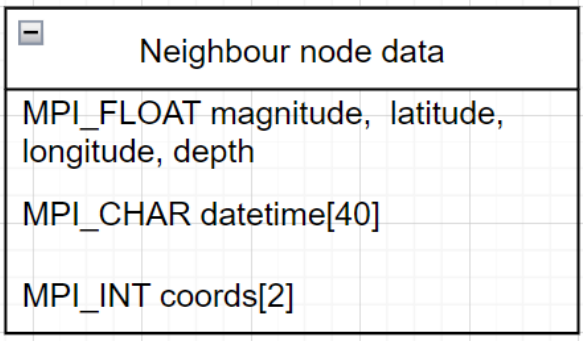


Figure 6. Neighbour node packed data

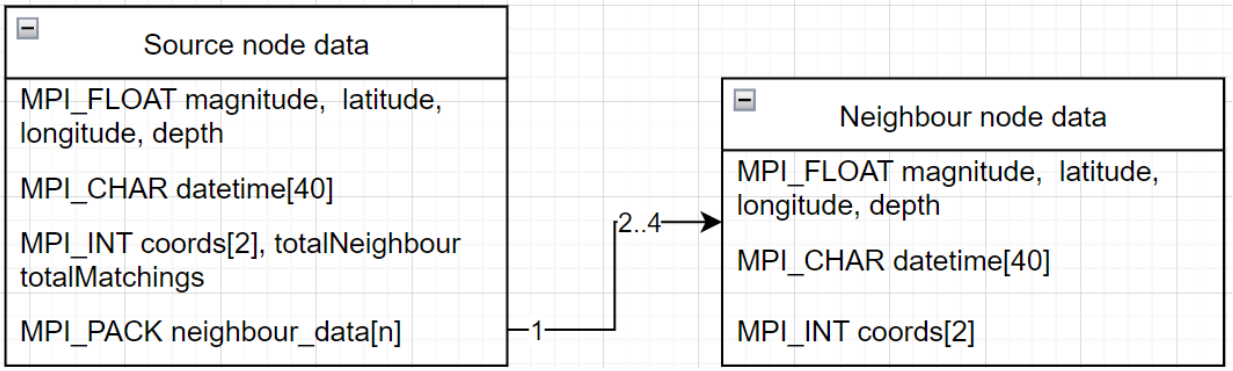


Figure 7. Source node packed data

For efficient communication between threads and processes, information is packed and unpacked as a single MPI_Pack data. Receive node thread sends information of its latest reading to the source node as Neighbour node data as shown in Figure 6. After generate node thread receives the packed information, it unpacks to perform calculation and comparison. Similarly, when the generate node thread alerts the base station, the information sent is packed as Source node data and unpacked when received by the alert thread.

The usage of non blocking probe shown in figure 4 prior to any MPI send or receive. Having sentinel value to terminate thread is not enough as MPI receive and send are blocking. It is possible when either one of the threads exits first, the other thread waits for a send or receive from the exited thread indefinitely. Thus, prior to each send or receive a probe is used such that the thread will only receive if there is a message sent from another thread and vice versa.

2. Balloon seismic sensor

```
balloon thread

function balloonThread(argsBalloon)
    data = cast argsBalloon to BalloonThread pointer data type
    initialize lock, timespec start and end, time_taken
    While data->sentinel != SENTINEL do
        clock_gettime into start
        mutex lock
        updateBalloonArray()
        mutex unlock
        clock_gettime into end
        sleep(cycle node - (end - start))
    end while
    thread exits
end function
```

Figure 8. Balloon thread implementation pseudocode

Figure 1 and 2 shows the balloon seismic sensor covering the whole area and is represented by a POSIX thread spawned by the base station MPI process. It generates a new reading per set time interval as listed in figure 3 and stores it in a global array. The array is set as a shared, static queue (First in First Out mechanism) of size 10. From pseudo code in figure 8, balloon thread runs continuously until a termination message is received from the base station. To avoid race conditions and inconsistent comparison when the array is read for comparison in the alert thread, a mutex lock is placed before and after a new reading is added into the array.

3. Base station

```
base station MPI process

initialize balloon thread with balloonThread function and argsBalloon
initialize alert thread with alertThread function and argsAlert
initialize sentinel to 0
if argc == 6 do
    for i = 1 to n do
        sleep(cycle node)
    end for
else
    while (1) do
        open "sentinel.txt" save to sentinelTxt
        scan sentinelTxt content save to sentinel
        close sentinelTxt

        if sentinel == SENTINEL do
            break
        end if
        sleep(cycle node)
        currentIteration+=1
end if
sentinel = SENTINEL
for i = 0 to p-1 do
    MPI_Send sentinel
end for
Clean up threads
```

```
function alertThread(argsAlert)
    initialize buffer, totalNeighbour, totalMatchings, sourceNode, adjacentNodes[4]
    initialize conclusive to false
    While sentinel != SENTINEL do
        initialize flag to false
        MPI_Iprobe into flag
        if flag is true then
            MPI_Recv into buffer
            totalNeighbour, totalMatchings, sourceNode, adjacentNodes[4] = MPI_Unpack buffer
        end if
        for i = 1 to 3 do
            balloonReading = getNthLatestBalloonReading()
            comparison = compareTwoReadings(balloonReading,sourceNode)
            if comparison.matching is true then
                conclusive = true
            end if
        end for
        write into logfile.txt
    end while
    thread exits
end function
```

Figure 9. Base station MPI process implementation pseudo code

As seen in figure 1 and 2, the base station is represented by an MPI process with two threads spawned, in addition to balloon thread in section 2, another thread is used to get alerts from seafloor nodes. Based on implementation pseudo code provided in figure 9, while the base station has not sent a termination signal yet, the alert thread unpacks the

received information as displayed in figure 6 and 7 whenever it receives a message from any seafloor node thread and compares the source node reading to the three newest readings stored in the balloon array to determine if an alert is conclusive or not before writing it to the log file. Non blocking probe is used prior to receiving packed information to ensure alert thread does not wait indefinitely if iterations have been completed and receive ocean node threads have exited.

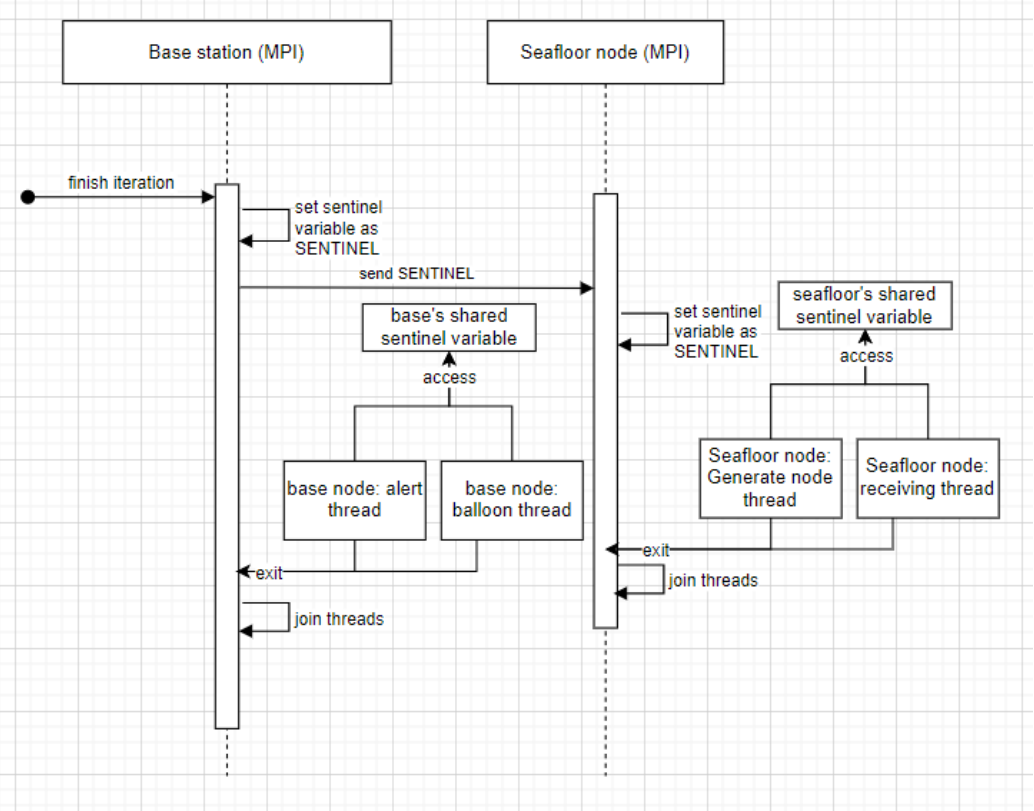


Figure 10. Simulation termination triggered by base station

Base station's MPI process controls the simulation. If the user specifies an additional 6th argument in the command line argument, the program runs a fixed number of iterations using the argument before setting a sentinel value. Else, user may set sentinel value of 2 in sentinel.txt to stop program during runtime. In each iteration, it sleeps for the interval set while other MPI processes and POSIX threads continue their executions. The simulation termination is displayed in figure 10, once the sentinel value is updated to stop termination, the base station sends it to all other MPI processes representing the seafloor nodes. Threads generated by all processes share the new sentinel value so they now can exit loop execution and terminate themselves. Each MPI process responsible for their spawned threads joins their threads together afterwards.

B. Results Tabulation

Experiment Setup

Multiple different simulations are run as shown in figure 11 with different grid sizes in a virtual machine (2048 MB base memory and 4 processors) and CAAS. Results from the log files generated are tabulated into figure 11 and 13. As our hypothesis focuses on the relation between number of neighbours and alerts sent, only the coordinate of the seafloor node that alerts the base station, total number of alerts received, and number of neighbours are included in our tabulation. Fixed number of iterations is used to ensure fairness in simulation.

grid size	magnitude	distance	iterations	run on vm	run on caas
4x3	1	1500	5	3	3
5x5	1	1500	5	3	3
10x10	1	1500	5	0	1

Figure 11. Simulations' specifications

Result

```
--------- Starting Earthquake Detection Simulation
********* Currently in iteration 1 ...
********* Currently in iteration 2 ...
********* Currently in iteration 3 ...
[fit3143:03546] 12 more processes have sent help message help-mpi-btl-base.txt / btl:no-nics
[fit3143:03546] Set MCA parameter "orte_base_help_aggregate" to 0 to see all help / error messages
********* Currently in iteration 4 ...
********* Currently in iteration 5 ...
--------- Earthquake Detection Simulation Completed
1|1|1|
3|2|4|
2|1|1|
0|0|0|

 Total alerts 16
```

Figure 12. Terminal messages print for simulation on VM, grid size 4x3, 1st run

```
4x3_run1_vm_logfile.txt
1   FIT3143 Assignment 2
2
3   MA Lab 6 Team 1
4   Editha Karina Hermawan 32179081
5   Lionie Annabella Wijaya 31316115
6
7   Ocean nodes dimension: 4x3
8   Coordinate different threshold (km): 1.000000
9   Magnitude different threshold: 1500.000000
10  Earthquake magnitude threshold: 2.500000
11  ----------
12  Iteration: 1
13  Logged time: 2022/10/16 19:22:40
14  Alert type: Inconclusive
15
16  Reporting Node:
17  Coord: (2,2) | Date and time: 2022/10/16 19:22:40| Seismic coord: (39.064659,35.051105)| Magnitude: 4.530895| Depth: 167.560913
18
19  2 out of 2 Adjacent Nodes matching to Reporting Node:
20  Coord: (3,2) | Date and time: 2022/10/16 19:22:40| Seismic coord: (45.976383,32.574245), Diff(coord,km): 695.168884 | Magnitude: 3.746505, Diff(mag) 0.784390| Depth: 117.363831
21  Coord: (2,1) | Date and time: 2022/10/16 19:22:40| Seismic coord: (33.829990,27.944328), Diff(coord,km): 932.734497 | Magnitude: 4.827484, Diff(mag) 0.296589| Depth: 135.723343
22
23  Balloon seismic reporting time: 2022/10/16 19:22:40
24  Balloon seismic reporting coord: (23.959221,30.115166)
25  Balloon seismic reporting coord diff. with reporting node: 1515.890015
26  Balloon seismic reporting magnitude: 2.528918
27  Balloon seismic reporting magnitude diff. with reporting node: 2.001977
```

Figure 13. Snippet of log file for simulation on VM, grid size 4x3, 1st run

```
--------- Starting Earthquake Detection Simulation
********* Currently in iteration 1 ...
********* Currently in iteration 2 ...
********* Currently in iteration 3 ...
[fit3143:03637] 12 more processes have sent help message help-mpi-btl-base.txt / btl:no-nics
[fit3143:03637] Set MCA parameter "orte_base_help_aggregate" to 0 to see all help / error messages
********* Currently in iteration 4 ...
********* Currently in iteration 5 ...
--------- Earthquake Detection Simulation Completed
1|1|1|
5|2|2|
2|2|2|
0|0|0|

 Total alerts 18
```

Figure 14. Terminal messages print for simulation on VM, grid size 4x3, 2nd run

```
4x3_run2_vm_logfile.txt
FIT3143 Assignment 2

MA Lab 6 Team 1
Editha Karina Hermawan 32179081
Lionie Annabella Wijaya 31316115

Ocean nodes dimension: 4x3
Coordinate different threshold (km): 1.000000
Magnitude different threshold: 1500.000000
Earthquake magnitude threshold: 2.500000
--------------------------------------------------------------------------------------------------------------------------------------------------------------
Iteration: 1
Logged time: 2022/10/16 19:25:30
Alert type: Conclusive

Reporting Node:
Coord: (1,1) | Date and time: 2022/10/16 19:25:30| Seismic coord: (33.307484,26.604805)| Magnitude: 6.713692| Depth: 40.476425

2 out of 2 Adjacent Nodes matching to Reporting Node:
Coord: (1,0) | Date and time: 2022/10/16 19:25:30| Seismic coord: (32.481380,21.350620), Diff(coord,km): 590.201599 | Magnitude: 5.793639, Diff(mag) 0.920053| Depth: 28.732637
Coord: (1,2) | Date and time: 2022/10/16 19:25:30| Seismic coord: (33.670166,35.017433), Diff(coord,km): 936.035156 | Magnitude: 6.688852, Diff(mag) 0.024840| Depth: 153.469803

Balloon seismic reporting time: 2022/10/16 19:25:30
Balloon seismic reporting coord: (32.257370,39.081360)
Balloon seismic reporting coord diff. with reporting node: 1390.696167
Balloon seismic reporting magnitude: 6.676284
Balloon seismic reporting magnitude diff. with reporting node: 0.037408
```

Figure 15. Snippet of log file for simulation on VM, grid size 4x3, 2nd run

```
--------- Starting Earthquake Detection Simulation
********* Currently in iteration 1 ...
********* Currently in iteration 2 ...
********* Currently in iteration 3 ...
[fit3143:03469] 12 more processes have sent help message help-mpi-btl-base.txt / btl:no-nics
[fit3143:03469] Set MCA parameter "orte_base_help_aggregate" to 0 to see all help / error messages
********* Currently in iteration 4 ...
********* Currently in iteration 5 ...
--------- Earthquake Detection Simulation Completed
2|1|2|
2|2|2|
4|4|2|
1|0|0|

 Total alerts 22
```

Figure 16. Terminal messages print for simulation on VM, grid size 4x3, 3rd run

```
4x3_run3_vm_logfile.txt
FIT3143 Assignment 2

MA Lab 6 Team 1
Editha Karina Hermawan 32179081
Lionie Annabella Wijaya 31316115

Ocean nodes dimension: 4x3
Coordinate different threshold (km): 1.000000
Magnitude different threshold: 1500.000000
Earthquake magnitude threshold: 2.500000
--------------------------------------------------------------------------------------------------------------------------------------------------------------
Iteration: 1
Logged time: 2022/10/16 19:27:29
Alert type: Inconclusive

Reporting Node:
Coord: (2,1) | Date and time: 2022/10/16 19:27:29| Seismic coord: (33.574177,30.756021)| Magnitude: 6.810638| Depth: 149.602280

2 out of 3 Adjacent Nodes matching to Reporting Node:
Coord: (3,1) | Date and time: 2022/10/16 19:27:29| Seismic coord: (43.331226,25.235794), Diff(coord,km): 1136.911865 | Magnitude: 6.003040, Diff(mag) 0.807598| Depth: 23.647131
Coord: (2,0) | Date and time: 2022/10/16 19:27:29| Seismic coord: (38.260796,20.584072), Diff(coord,km): 1224.247070 | Magnitude: 5.067257, Diff(mag) 1.743381| Depth: 116.044540
Coord: (2,2) | Date and time: 2022/10/16 19:27:29| Seismic coord: (37.366035,32.728973), Diff(coord,km): 420.288086 | Magnitude: 6.132130, Diff(mag) 0.678508| Depth: 150.381470

Balloon seismic reporting time: 2022/10/16 19:27:28
Balloon seismic reporting coord: (37.690483,33.296432)
Balloon seismic reporting coord diff. with reporting node: 479.880188
Balloon seismic reporting magnitude: 5.721364
Balloon seismic reporting magnitude diff. with reporting node: 1.089273
```

Figure 17. Snippet of log file for simulation on VM, grid size 4x3, 3rd run

```
--------- Starting Earthquake Detection Simulation
********* Currently in iteration 1 ...
********* Currently in iteration 2 ...
[fit3143:04533] 25 more processes have sent help message help-mpi-btl-base.txt / btl:no-nics
[fit3143:04533] Set MCA parameter "orte_base_help_aggregate" to 0 to see all help / error messages
********* Currently in iteration 3 ...
********* Currently in iteration 4 ...
********* Currently in iteration 5 ...
--------- Earthquake Detection Simulation Completed
1|2|1|3|0|
3|3|3|2|2|
3|2|3|2|2|
2|3|2|1|0|
1|2|0|0|0|

 Total alerts 43
```

Figure 18. Terminal messages print for simulation on VM, grid size 5x5, 1st run

```
5x5_run1_vm_logfile.txt
1   FIT3143 Assignment 2
2
3   MA Lab 6 Team 1
4   Editha Karina Hermawan 32179081
5   Lionie Annabella Wijaya 31316115
6
7   Ocean nodes dimension: 5x5
8   Coordinate different threshold (km): 1.000000
9   Magnitude different threshold: 1500.000000
10  Earthquake magnitude threshold: 2.500000
11  ----------
12  Iteration: 1
13  Logged time: 2022/10/16 20:10:38
14  Alert type: Inconclusive
15
16  Reporting Node:
17  Coord: (1,4) | Date and time: 2022/10/16 20:10:38| Seismic coord: (28.497866,39.432190)| Magnitude: 5.060394| Depth: 96.929283
18
19  2 out of 2 Adjacent Nodes matching to Reporting Node:
20  Coord: (2,4) | Date and time: 2022/10/16 20:10:38| Seismic coord: (29.980183,36.658726), Diff(coord,km): 334.568726 | Magnitude: 5.742450, Diff(mag) 0.682056| Depth: 112.940941
21  Coord: (1,3) | Date and time: 2022/10/16 20:10:38| Seismic coord: (24.710981,32.011810), Diff(coord,km): 892.840271 | Magnitude: 5.345140, Diff(mag) 0.284746| Depth: 139.810165
22
23  Balloon seismic reporting time: 2022/10/16 20:10:37
24  Balloon seismic reporting coord: (36.050297,23.015926)
25  Balloon seismic reporting coord diff. with reporting node: 1959.544678
26  Balloon seismic reporting magnitude: 5.726788
27  Balloon seismic reporting magnitude diff. with reporting node: 0.666393
```

Figure 19. Snippet of log file for simulation on VM, grid size 5x5, 1st run

```
--------- Starting Earthquake Detection Simulation
********* Currently in iteration 1 ...
********* Currently in iteration 2 ...
[fit3143:04680] 25 more processes have sent help message help-mpi-btl-base.txt / btl:no-nics
[fit3143:04680] Set MCA parameter "orte_base_help_aggregate" to 0 to see all help / error messages
********* Currently in iteration 3 ...
********* Currently in iteration 4 ...
********* Currently in iteration 5 ...
--------- Earthquake Detection Simulation Completed
0|1|2|1|0|
2|3|1|3|2|
2|3|1|2|2|
1|4|2|4|3|
0|2|1|1|0|

 Total alerts 43
```

Figure 20. Terminal messages print for simulation on VM, grid size 5x5, 2nd run

```
5x5_run2_vm_logfile.txt
1   FIT3143 Assignment 2
2
3   MA Lab 6 Team 1
4   Editha Karina Hermawan 32179081
5   Lionie Annabella Wijaya 31316115
6
7   Ocean nodes dimension: 5x5
8   Coordinate different threshold (km): 1.000000
9   Magnitude different threshold: 1500.000000
10  Earthquake magnitude threshold: 2.500000
11  ----------
12  Iteration: 1
13  Logged time: 2022/10/16 20:14:10
14  Alert type: Inconclusive
15
16  Reporting Node:
17  Coord: (2,1) | Date and time: 2022/10/16 20:14:10| Seismic coord: (30.748585,24.567383)| Magnitude: 4.590124| Depth: 135.623413
18
19  2 out of 3 Adjacent Nodes matching to Reporting Node:
20  Coord: (3,1) | Date and time: 2022/10/16 20:14:10| Seismic coord: (33.384106,26.841141), Diff(coord,km): 365.538849 | Magnitude: 4.885407, Diff(mag) 0.295284| Depth: 49.642853
21  Coord: (2,0) | Date and time: 2022/10/16 20:14:10| Seismic coord: (31.745077,21.242609), Diff(coord,km): 383.504639 | Magnitude: 4.863344, Diff(mag) 0.273221| Depth: 27.998302
22  Coord: (2,2) | Date and time: 2022/10/16 20:14:10| Seismic coord: (32.183147,32.709435), Diff(coord,km): 916.037231 | Magnitude: 6.340201, Diff(mag) 1.750078| Depth: 169.546997
23
24  Balloon seismic reporting time: 2022/10/16 20:14:10
25  Balloon seismic reporting coord: (23.319729,26.231560)
26  Balloon seismic reporting coord diff. with reporting node: 768.633545
27  Balloon seismic reporting magnitude: 3.373231
28  Balloon seismic reporting magnitude diff. with reporting node: 1.216892
```

Figure 21. Snippet of log file for simulation on VM, grid size 5x5m, 2nd run

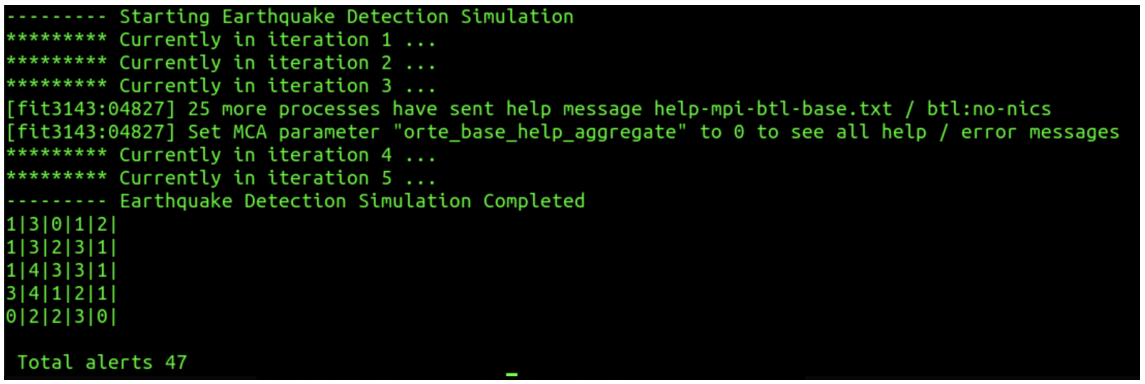


Figure 22. Terminal messages print for simulation on VM, grid size 5x5, 3rd run

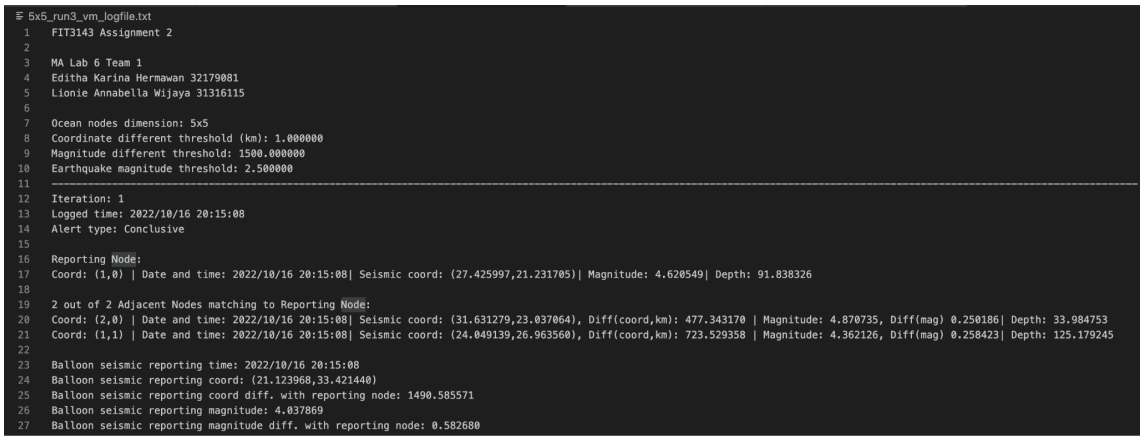


Figure 23. Snippet of log file for simulation on VM, grid size 5x5, 3rd run

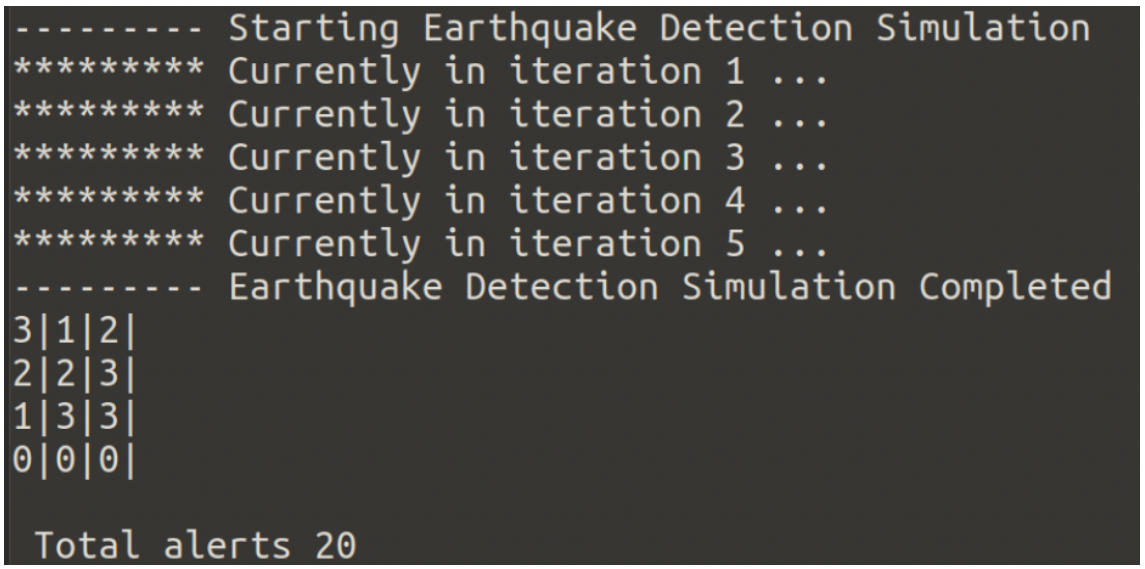
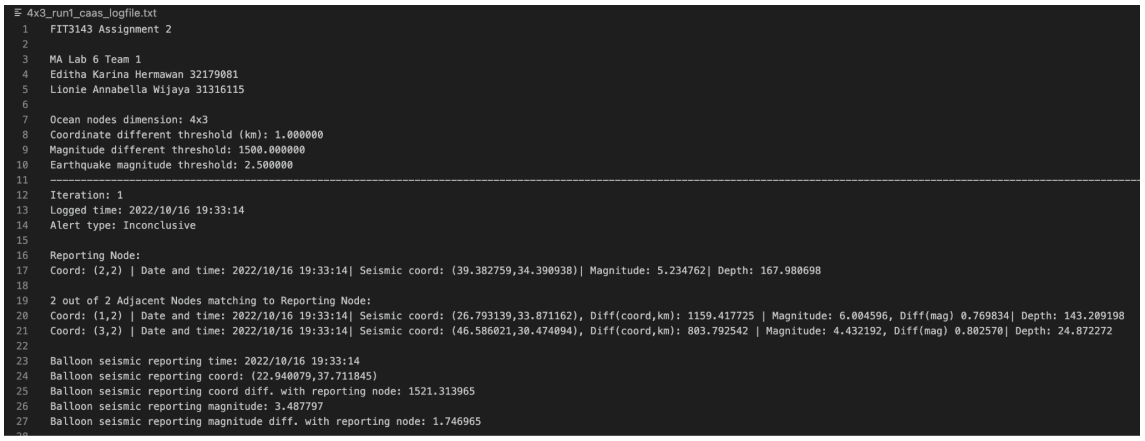
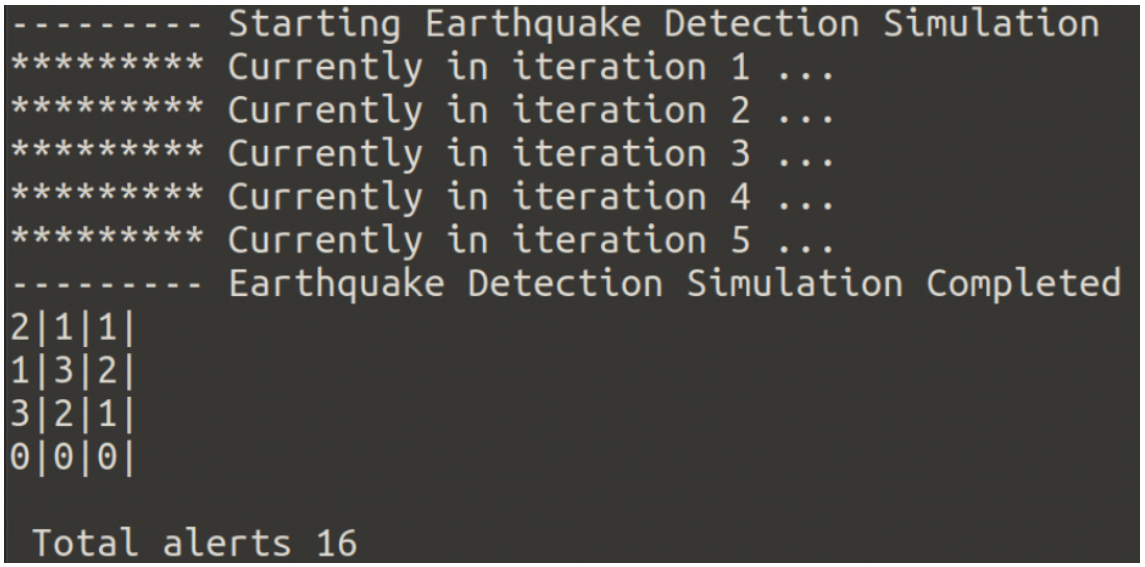


Figure 24. Terminal messages print for simulation on CAaS, grid size 4x3, 1st run



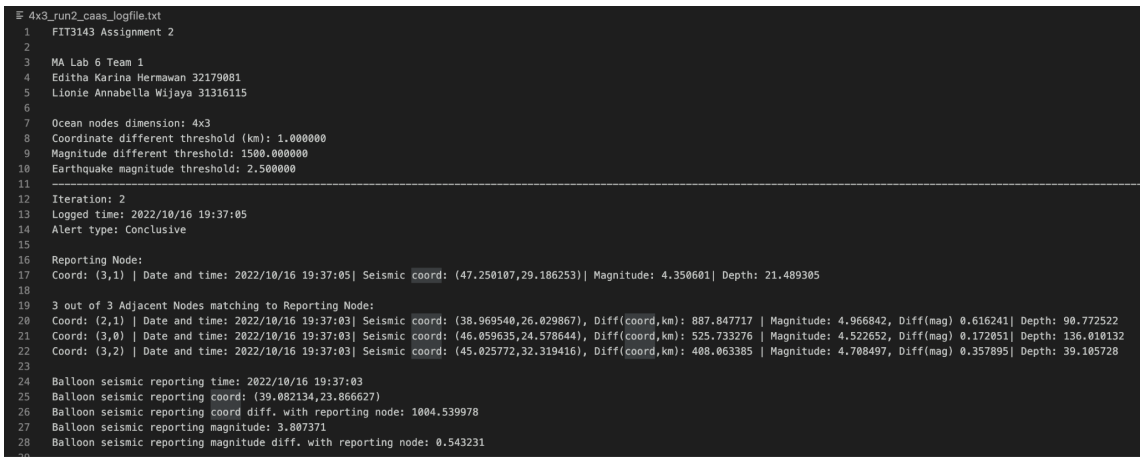
```
4x3_run1_caas_logfile.txt
1   FIT3143 Assignment 2
2
3   MA Lab 6 Team 1
4   Editha Karina Hermawan 32179081
5   Lionie Annabella Wijaya 31316115
6
7   Ocean nodes dimension: 4x3
8   Coordinate different threshold (km): 1.000000
9   Magnitude different threshold: 1500.000000
10  Earthquake magnitude threshold: 2.500000
11  ----------
12  Iteration: 1
13  Logged time: 2022/10/16 19:33:14
14  Alert type: Inconclusive
15
16  Reporting Node:
17  Coord: (2,2) | Date and time: 2022/10/16 19:33:14| Seismic coord: (39.382759,34.390938)| Magnitude: 5.234762| Depth: 167.980698
18
19  2 out of 2 Adjacent Nodes matching to Reporting Node:
20  Coord: (1,2) | Date and time: 2022/10/16 19:33:14| Seismic coord: (26.793139,33.871162), Diff(coord,km): 1159.417725 | Magnitude: 6.004596, Diff(mag) 0.769834| Depth: 143.209198
21  Coord: (3,2) | Date and time: 2022/10/16 19:33:14| Seismic coord: (46.586021,30.474094), Diff(coord,km): 803.792542 | Magnitude: 4.432192, Diff(mag) 0.802570| Depth: 24.872272
22
23  Balloon seismic reporting time: 2022/10/16 19:33:14
24  Balloon seismic reporting coord: (22.940079,37.711845)
25  Balloon seismic reporting coord diff. with reporting node: 1521.313965
26  Balloon seismic reporting magnitude: 3.487797
27  Balloon seismic reporting magnitude diff. with reporting node: 1.746965
```

Figure 25. Snippet of log file for simulation on CAaS, grid size 4x3, 1st run



```
--------- Starting Earthquake Detection Simulation
********* Currently in iteration 1 ...
********* Currently in iteration 2 ...
********* Currently in iteration 3 ...
********* Currently in iteration 4 ...
********* Currently in iteration 5 ...
--------- Earthquake Detection Simulation Completed
2|1|1|
1|3|2|
3|2|1|
0|0|0|

 Total alerts 16
```

Figure 26. Terminal messages print for simulation on CAaS, grid size 4x3, 2nd run



```
4x3_run2_caas_logfile.txt
1   FIT3143 Assignment 2
2
3   MA Lab 6 Team 1
4   Editha Karina Hermawan 32179081
5   Lionie Annabella Wijaya 31316115
6
7   Ocean nodes dimension: 4x3
8   Coordinate different threshold (km): 1.000000
9   Magnitude different threshold: 1500.000000
10  Earthquake magnitude threshold: 2.500000
11  ----------
12  Iteration: 2
13  Logged time: 2022/10/16 19:37:05
14  Alert type: Conclusive
15
16  Reporting Node:
17  Coord: (3,1) | Date and time: 2022/10/16 19:37:05| Seismic coord: (47.250107,29.186253)| Magnitude: 4.350601| Depth: 21.489305
18
19  3 out of 3 Adjacent Nodes matching to Reporting Node:
20  Coord: (2,1) | Date and time: 2022/10/16 19:37:03| Seismic coord: (38.969540,26.029867), Diff(coord,km): 887.847717 | Magnitude: 4.966842, Diff(mag) 0.616241| Depth: 90.772522
21  Coord: (3,0) | Date and time: 2022/10/16 19:37:03| Seismic coord: (46.059635,24.578644), Diff(coord,km): 525.733276 | Magnitude: 4.522652, Diff(mag) 0.172051| Depth: 136.010132
22  Coord: (3,2) | Date and time: 2022/10/16 19:37:03| Seismic coord: (45.025772,32.319416), Diff(coord,km): 408.063385 | Magnitude: 4.708497, Diff(mag) 0.357895| Depth: 39.105728
23
24  Balloon seismic reporting time: 2022/10/16 19:37:03
25  Balloon seismic reporting coord: (39.082134,23.866627)
26  Balloon seismic reporting coord diff. with reporting node: 1004.539978
27  Balloon seismic reporting magnitude: 3.807371
28  Balloon seismic reporting magnitude diff. with reporting node: 0.543231
```

Figure 27. Snippet of log file for simulation on CAaS, grid size 4x3, 2nd run

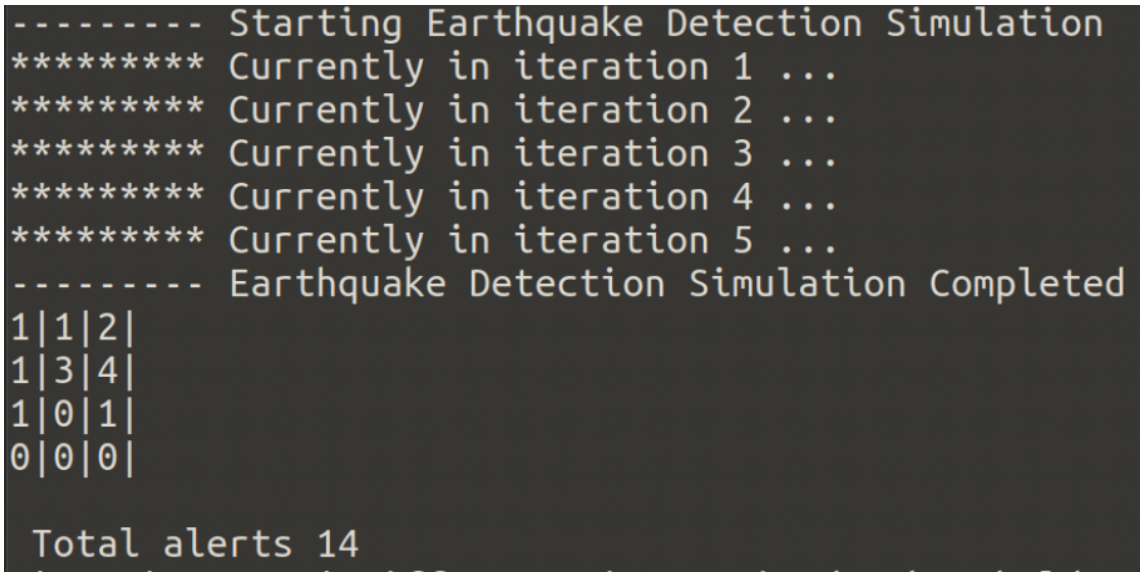


Figure 28. Terminal messages print for simulation on CAaS, grid size 4x3, 3rd run

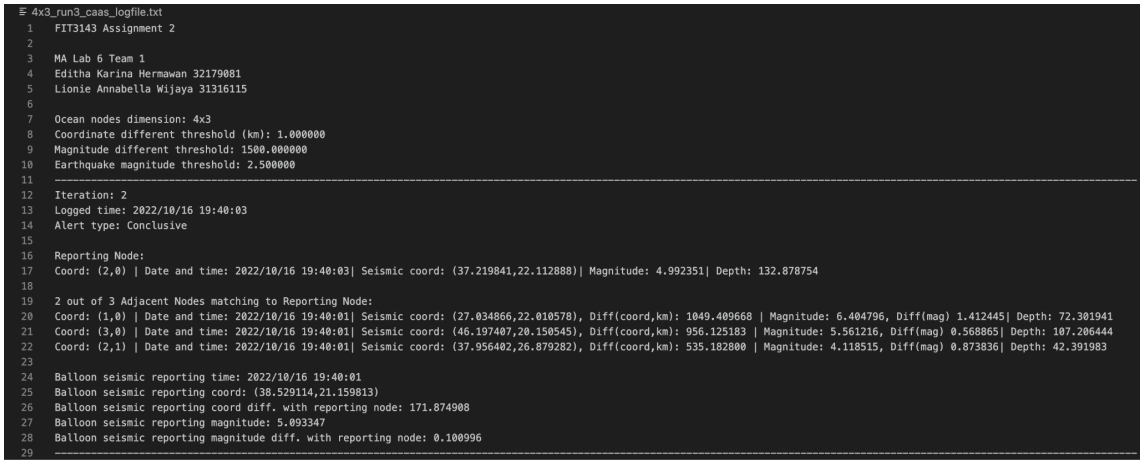


Figure 29. Snippet of log file for simulation on CAaS, grid size 4x3, 3rd run

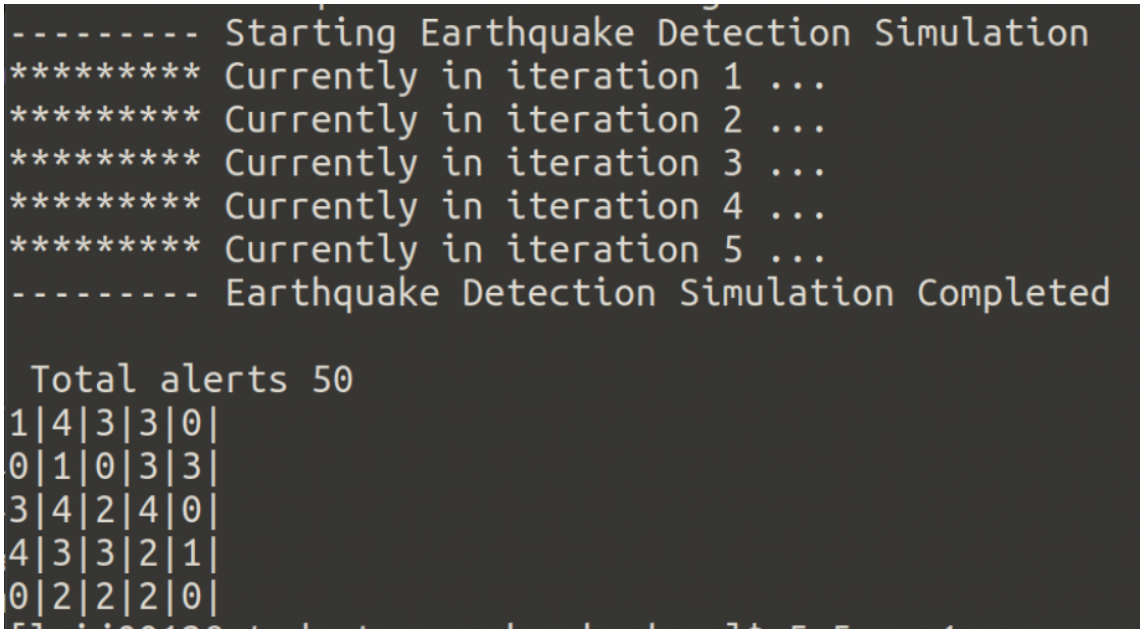
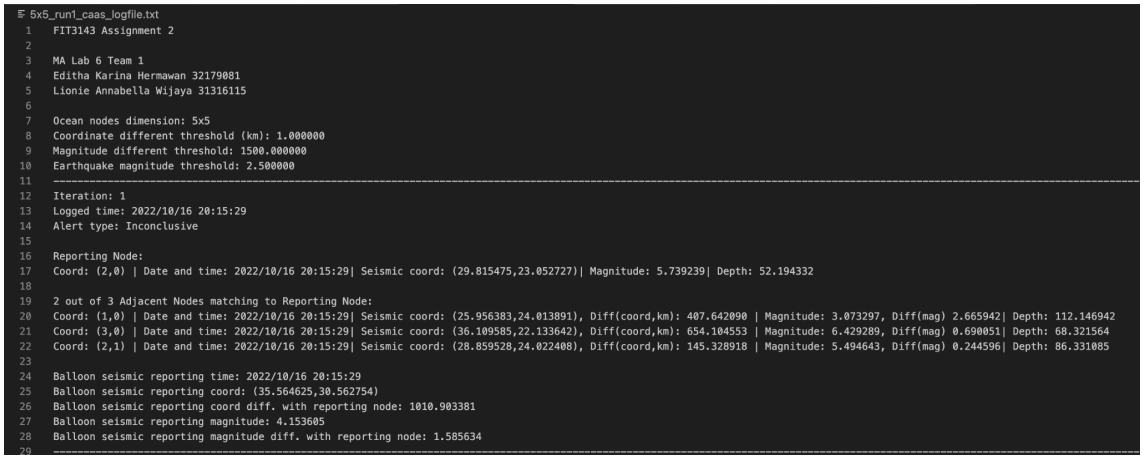


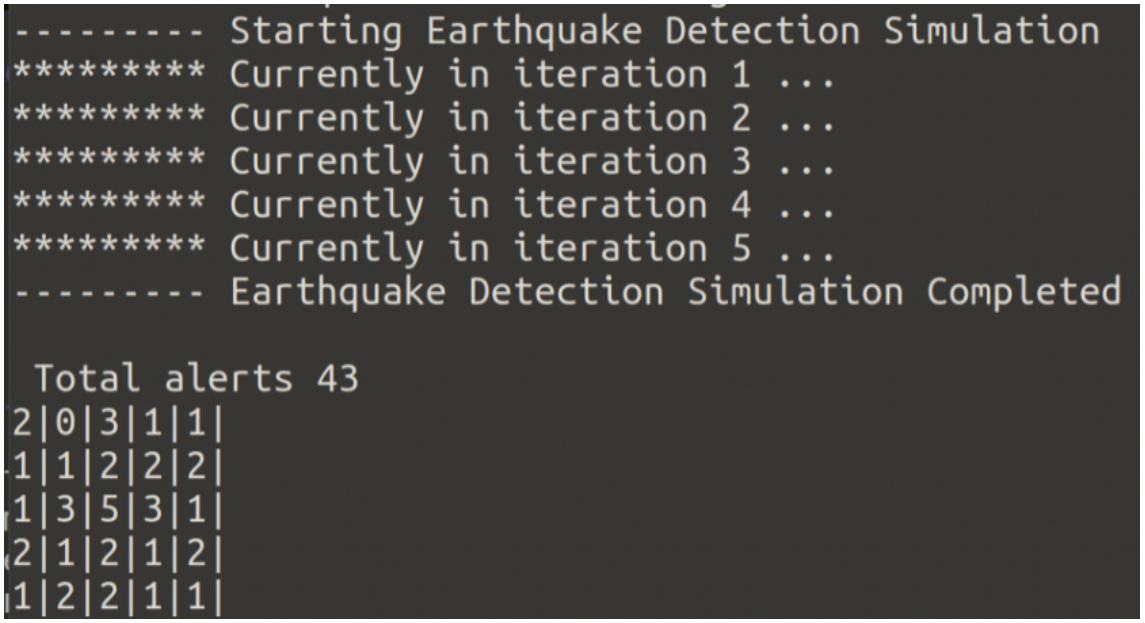
Figure 30. Terminal messages print for simulation on CAaS, grid size 5x5, 1st run



5x5_run1_caas_logfile.txt

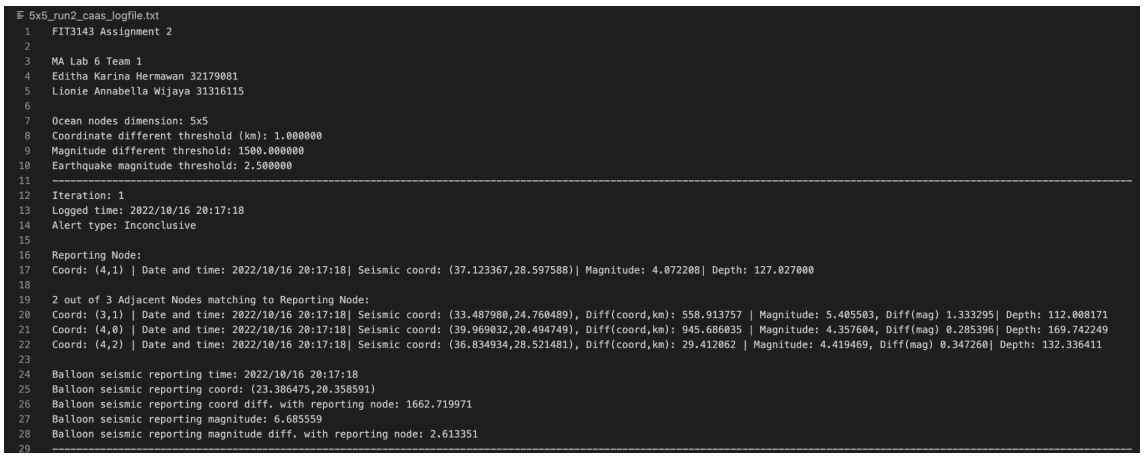
```
FIT3143 Assignment 2

MA Lab 6 Team 1
Editha Karina Hermawan 32179081
Lionie Annabella Wijaya 31316115

Ocean nodes dimension: 5x5
Coordinate different threshold (km): 1.000000
Magnitude different threshold: 1500.000000
Earthquake magnitude threshold: 2.500000
--------------------------------------------------------------------------------------------------------------------------------------------------------------
Iteration: 1
Logged time: 2022/10/16 20:15:29
Alert type: Inconclusive

Reporting Node:
Coord: (2,0) | Date and time: 2022/10/16 20:15:29| Seismic coord: (29.815475,23.052727)| Magnitude: 5.739239| Depth: 52.194332

2 out of 3 Adjacent Nodes matching to Reporting Node:
Coord: (1,0) | Date and time: 2022/10/16 20:15:29| Seismic coord: (25.956383,24.013891), Diff(coord,km): 407.642090 | Magnitude: 3.073297, Diff(mag) 2.665942| Depth: 112.146942
Coord: (3,0) | Date and time: 2022/10/16 20:15:29| Seismic coord: (36.109585,22.133642), Diff(coord,km): 654.104553 | Magnitude: 6.429289, Diff(mag) 0.690051| Depth: 68.321564
Coord: (2,1) | Date and time: 2022/10/16 20:15:29| Seismic coord: (28.859528,24.022408), Diff(coord,km): 145.328918 | Magnitude: 5.494643, Diff(mag) 0.244596| Depth: 86.331085

Balloon seismic reporting time: 2022/10/16 20:15:29
Balloon seismic reporting coord: (35.564625,30.562754)
Balloon seismic reporting coord diff. with reporting node: 1010.903381
Balloon seismic reporting magnitude: 4.153605
Balloon seismic reporting magnitude diff. with reporting node: 1.585634
--------------------------------------------------------------------------------------------------------------------------------------------------------------
```

Figure 31. Snippet of log file for simulation on CAaS, grid size 5x5, 1st run



```
--------- Starting Earthquake Detection Simulation
********* Currently in iteration 1 ...
********* Currently in iteration 2 ...
********* Currently in iteration 3 ...
********* Currently in iteration 4 ...
********* Currently in iteration 5 ...
--------- Earthquake Detection Simulation Completed

 Total alerts 43
2|0|3|1|1|
1|1|2|2|2|
1|3|5|3|1|
2|1|2|1|2|
1|2|2|1|1|
```

Figure 32. Terminal messages print for simulation on CAaS, grid size 5x5, 2nd run



5x5_run2_caas_logfile.txt

```
FIT3143 Assignment 2

MA Lab 6 Team 1
Editha Karina Hermawan 32179081
Lionie Annabella Wijaya 31316115

Ocean nodes dimension: 5x5
Coordinate different threshold (km): 1.000000
Magnitude different threshold: 1500.000000
Earthquake magnitude threshold: 2.500000
--------------------------------------------------------------------------------------------------------------------------------------------------------------
Iteration: 1
Logged time: 2022/10/16 20:17:18
Alert type: Inconclusive

Reporting Node:
Coord: (4,1) | Date and time: 2022/10/16 20:17:18| Seismic coord: (37.123367,28.597588)| Magnitude: 4.072208| Depth: 127.027000

2 out of 3 Adjacent Nodes matching to Reporting Node:
Coord: (3,1) | Date and time: 2022/10/16 20:17:18| Seismic coord: (33.487980,24.760489), Diff(coord,km): 558.913757 | Magnitude: 5.405503, Diff(mag) 1.333295| Depth: 112.008171
Coord: (4,0) | Date and time: 2022/10/16 20:17:18| Seismic coord: (39.969032,20.494749), Diff(coord,km): 945.686035 | Magnitude: 4.357604, Diff(mag) 0.285396| Depth: 169.742249
Coord: (4,2) | Date and time: 2022/10/16 20:17:18| Seismic coord: (36.834934,28.521481), Diff(coord,km): 29.412062 | Magnitude: 4.419469, Diff(mag) 0.347260| Depth: 132.336411

Balloon seismic reporting time: 2022/10/16 20:17:18
Balloon seismic reporting coord: (23.386475,20.358591)
Balloon seismic reporting coord diff. with reporting node: 1662.719971
Balloon seismic reporting magnitude: 6.685559
Balloon seismic reporting magnitude diff. with reporting node: 2.613351
--------------------------------------------------------------------------------------------------------------------------------------------------------------
```

Figure 33. Snippet of log file for simulation on CAaS, grid size 5x5, 2nd run

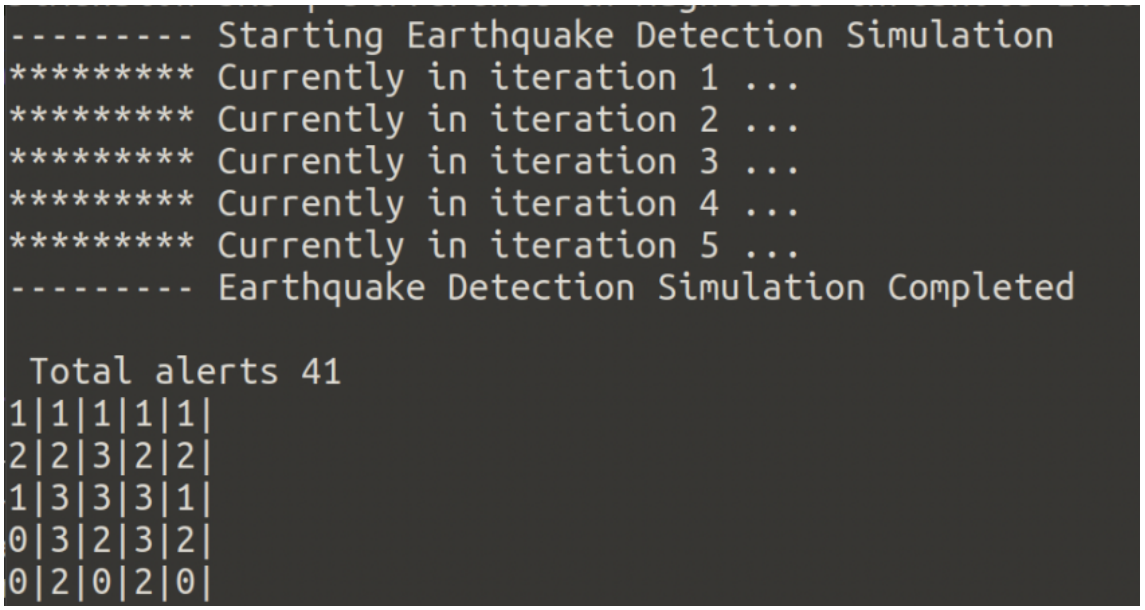


Figure 34. Terminal messages print for simulation on CAaS, grid size 5x5, 3rd run

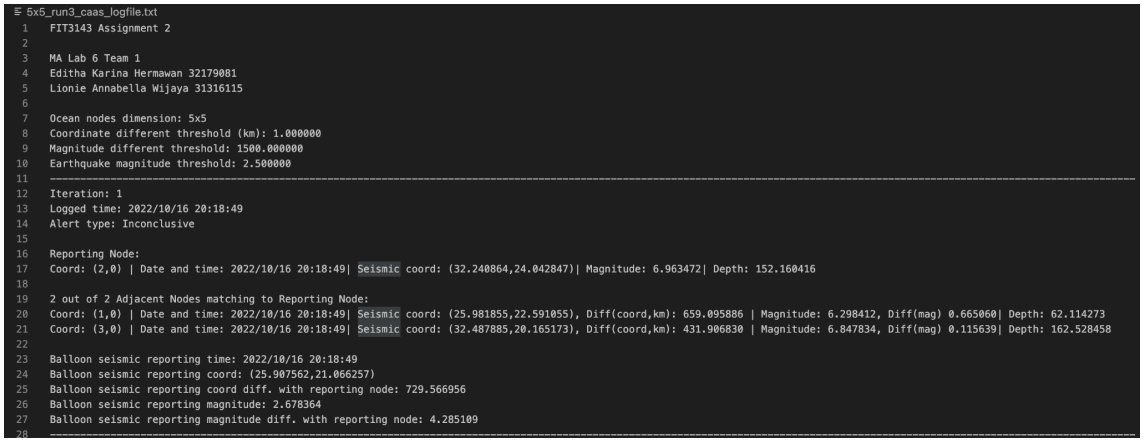


Figure 35. Snippet of log file for simulation on CAaS, grid size 5x5, 3rd run

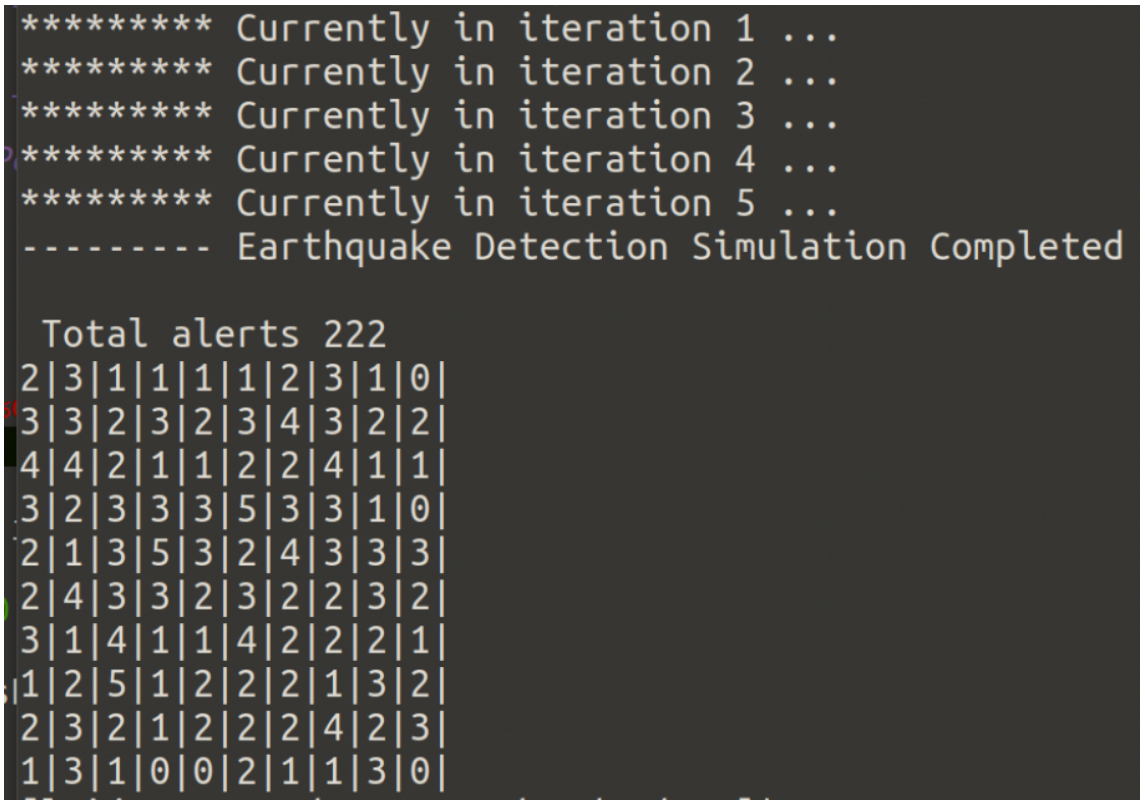


Figure 36. Terminal messages print for simulation on CAaS, grid size 10x10, 1st run

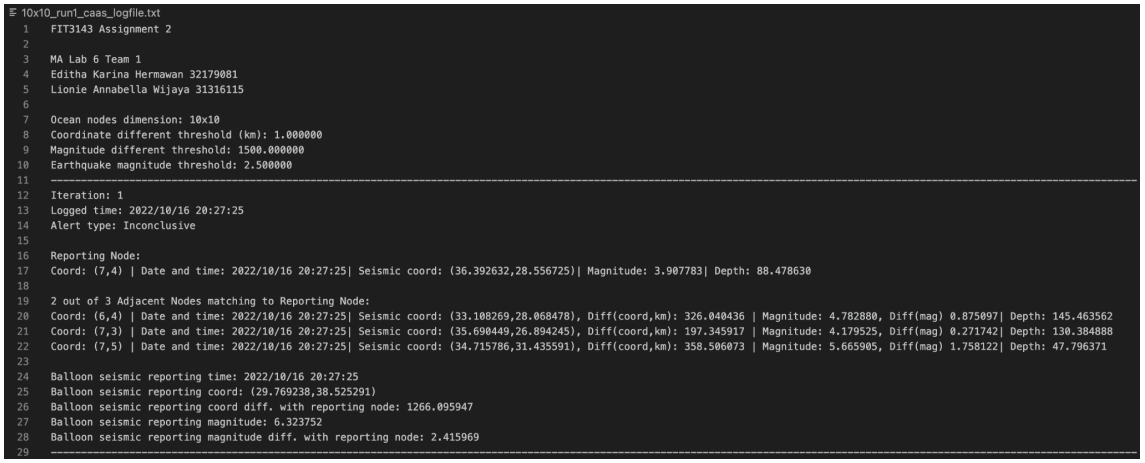


Figure 37. Snippet of log file for simulation on CAaS, grid size 10x10, 1st run

vm run 1

4x3

y \ x	0	1	2
0	2	1	2
1	2	2	2
2	4	4	2
3	1	0	0
Total alerts	22		

5x5

y \ x	0	1	2	3	4
0	1	2	1	3	0
1	3	3	3	2	2
2	3	2	3	2	2
3	2	3	2	1	0
4	1	2	0	0	0
Total alerts	43				

vm run 2

4x3

y \ x	0	1	2
0	1	1	1
1	3	2	4
2	2	1	1
3	0	0	0
Total alerts	16		

5x5

y \ x	0	1	2	3	4
0	0	1	2	1	0
1	2	3	1	3	2
2	2	3	1	2	2
3	1	4	2	4	3
4	0	2	1	1	0
Total alerts	43				

vm run 3

4x3

y \ x	0	1	2
0	1	1	1
1	5	2	2
2	2	2	2
3	0	0	0
Total alerts	18		

5x5

y \ x	0	1	2	3	4
0	1	3	0	1	2
1	1	3	2	3	1
2	1	4	3	3	1
3	3	4	1	2	1
4	0	2	2	3	0
Total alerts	47				

caas run 1

4x3

y \ x	0	1	2
0	3	1	2
1	2	2	3
2	1	3	3
3	0	0	0
Total alerts	20		

5x5

y \ x	0	1	2	3	4
0	1	4	3	3	0
1	0	1	0	3	3
2	3	4	2	4	0
3	4	3	3	2	1
4	0	2	2	2	0
Total alerts	50				

caas run 2

4x3

y \ x	0	1	2
0	2	1	1
1	1	3	2
2	3	2	1
3	0	0	0
Total alerts	16		

5x5

y \ x	0	1	2	3	4
0	2	0	3	1	1
1	1	1	2	2	2
2	1	3	5	3	1
3	2	1	2	1	2
4	1	2	2	1	1
Total alerts	43				

caas run 3

4x3

y \ x	0	1	2
0	1	1	2
1	1	3	4
2	1	0	1
3	0	0	0
Total alerts	14		

5x5

y \ x	0	1	2	3	4
0	1	1	1	1	1
1	2	2	3	2	2
2	1	3	3	3	1
3	0	3	2	3	2
4	0	2	0	2	0
Total alerts	41				

caas run 1

10x10

y \ x	0	1	2	3	4	5	6	7	8	9
0	2	3	1	1	1	1	2	3	1	0
1	3	3	2	3	2	3	4	3	2	2
2	4	4	2	1	1	2	2	4	1	1
3	3	2	3	3	3	5	3	3	1	0
4	2	1	3	5	3	2	4	3	3	3
5	2	4	3	3	2	3	2	2	3	2
6	3	1	4	1	1	4	2	2	2	1
7	1	2	5	1	2	2	2	1	3	2
8	2	3	2	1	2	2	2	4	2	3
9	1	3	1	0	0	2	1	1	3	0
Total alerts	222									

Figure 38. Simulation result, number in each cell represents the sum of alerts sent by the node in coordinate (x,y) where columns represent x and rows represent y

caas	average alerts
4x3	
2 neighbours	0.9166666667
3 neighbours	1.444444444
4 neighbours	2.166666667
5x5	
2 neighbours	0.6666666667
3 neighbours	1.666666667
4 neighbours	2.392857143
10x10	
2 neighbours	0.75
3 neighbours	1.8125
4 neighbours	2.515625

vm	average alerts
4x3	
2 neighbours	0.75
3 neighbours	1.888888889
4 neighbours	2.166666667
5x5	
2 neighbours	0.4166666667
3 neighbours	1.638888889
4 neighbours	2.555555556

Figure 39. Average simulation statistics

C. Analysis & Discussion

Hypothesis

The amount of communication with the base station will be most dense in the middle of the grid due to an increased number of neighbours and communication between the nodes leading to a higher chance of successful event detection

Observation

In general, the number of alerts tends to increase if a node has more neighbours, which is easily observed in larger grid sizes. As figure 39 shows, our hypothesis is held. For all grid sizes and platforms tested, the average number of total alerts increases in respect to the number of neighbours. Nodes located in the middle of the topology in purple cells have the highest average number of alerts, followed by non-corner and corner nodes in white and blue cells respectively. An alert is sent only if a node has minimal two neighbour nodes with matching readings, thus having more neighbours naturally increases the chance of triggering an alert.

Hypothesis still follows even when different platforms are used as the number of alerts is affected by the number of neighbours which relates to grid size and has no correlation to platforms. We do notice a difference in simulation time where simulation is completed faster in CAaS. This is because VM can only run 4 processes and oversubscribing is done to enable larger grid size but at the end all 4 processes handle tasks supposedly done by other processes whereas CAaS have processors to run all MPI processes parallely. However, this is based on observation during simulation, no tabulation is done as it is irrelevant to our hypothesis. Further simulations are needed to confirm this.

Limitations and Improvements

The limitation of our implementation is a less accurate log file due to usage of probe and sentinel value checking. Once all iterations are completed in the base station, all threads exit accordingly. This means we can no longer log alerts received from any seafloor nodes including new alerts sent before threads spawned by seafloor nodes exit as well as previous alerts still in queue to be written to the log file. This is even more prominent when grid size specified is large as larger grid size increases higher chance of alerts, leading to higher alerts sent per iteration and longer queue to write, which eventually leads to more alerts lost. A possible solution is to follow a fixed ordering in terminating threads and add conditional checking for alert thread. To elaborate, ensure no more ocean nodes send alerts to base stations after iterations are completed, which can be done by terminating threads spawned by seafloor nodes before alert thread is terminated. In addition, as there may still be alerts left to be written prior to simulation termination, additional checking can be done in the alert thread to continuously receive alerts even after sentinel value is updated until it exceeds a specified waiting time, meaning it has logged all alerts in the queue.

D. References

(2022). Retrieved 17 October 2022, from https://www.geodatasource.com/developers/c.

C, H., & Bogdan, S. (2022). *How to generate random float number in C*. Stack Overflow. Retrieved 17 October 2022, from https://stackoverflow.com/questions/13408990/how-to-generate-random-float-number-in-c. Declaration:

Earthquake Magnitude Scale | Michigan Technological University. Michigan Technological University. (2022). Retrieved 17 October 2022, from https://www.mtu.edu/geo/community/seismology/learn/earthquake-measure/magnitude/.

MONASH University

I declare that this assignment report and the submitted code represent work within my team. I have not copied from any other teams' work or from any other source except where due acknowledgment is made explicitly in the report and code, nor has any part of this submission been written for me by another person outside of my team.

Signature of student 1: Editha Karina Hermawan

Signature of student 2: Lionie Annabella Wijaya