

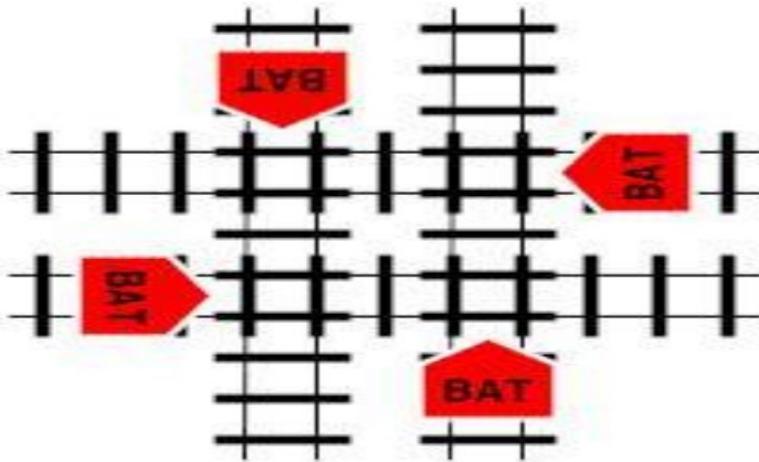
Operating System

BatMan

Synchronization & Mutual Exclusion

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Introduction

A company has employed a Bidirectional Autonomous Trolley (BAT) system to move products from its warehouses to the delivery trucks. Each BAT is a mobile platform that travels on separate tracks back and forth between a warehouse and a truck. At most one BAT can cross at a time. Traffic at the crossing arriving from the right has the right of way (i.e. East waits till North passes. North waits till West passes and so on).

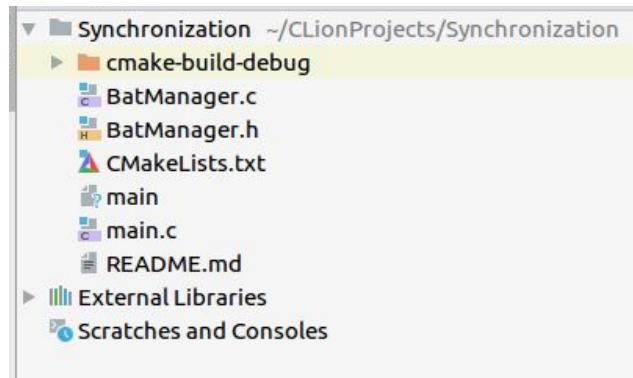
Terminology :-

- BATs arriving from the same direction line up behind the first BAT already at the crossing;
- BATs arriving from the right always have the right of way (unless the waiting BAT receives a signal to go);
- Deadlock has to be prevented
- Starvation has to be prevented.

The way to achieve each goal:

Line Up behind the first bat	I use only one mutual lock to make only one bat in arrive function then I use four condition variable to wait on each direction and use four counter to count the bats on the queue.
The right always have the right of way	In the crossing function have other 4 condition variable to wait on the right and 4 counter to count the number of bats which wait for the right
Prevent deadlock	On each success arrive I call function check and use a counter which count the number of bat in the cross If they are four then the deadlock is occurred and I signal the north bat to cross
Prevent starvation	After cross the crossing I signal the left bat to cross to prevent starvation.

Code Analysis :-



Main :-

```
int main() {
    initialize(); // initialize all condition variable, all mutex lock and counters
    scanf( "%s" , &directions[0]); // take direction from the user
    int len = strlen(directions);
    pthread_t bat[len]; //array of threads every thread is response of different bat
    pthread_attr_t attr [len];
    crossingCounter = 0;
    for(int i = 0; i < len; i++) {
        pthread_attr_init(&attr[i]);
        int *arg = malloc(sizeof(*arg));
        if ( arg == NULL ) {
            fprintf(stderr, "Couldn't allocate memory for thread arg.\n");
            exit(EXIT_FAILURE);
        }
        *arg = i;
        pthread_create(&bat[i], &attr[i], batOperation, arg); //create new thread
        pthread_attr_destroy(&attr[i]);
    }
    for(int i=0; i<len; i++)
    {
        pthread_join(bat[i], &status);
    }
    destroy(); //destroy all condition variable that is no longer be used
    pthread_exit(NULL);
}
```

```

void initialize(){
    pthread_mutex_init(&mutexMonitor, NULL);
    pthread_cond_init (&NorthQueue, NULL);
    pthread_cond_init (&EastQueue, NULL);
    pthread_cond_init (&SouthQueue, NULL);
    pthread_cond_init (&WestQueue, NULL);
    pthread_cond_init (&NorthFirst, NULL);
    pthread_cond_init (&EastFirst, NULL);
    pthread_cond_init (&SouthFirst, NULL);
    pthread_cond_init (&WestFirst, NULL);
    northCounter = 0;
    southCounter = 0;
    eastCounter = 0;
    westCounter = 0;
    crossingCounter = 0;
    waitEast = 0;
    waitNorth = 0;
    waitSouth = 0;
    waitWest = 0;
}
void destroy(){
    pthread_cond_destroy(&NorthQueue);
    pthread_cond_destroy(&EastQueue);
    pthread_cond_destroy(&SouthQueue);
    pthread_cond_destroy(&WestQueue);
    pthread_cond_destroy(&NorthFirst);
    pthread_cond_destroy(&EastFirst);
    pthread_cond_destroy(&SouthFirst);
    pthread_cond_destroy(&WestFirst);
    pthread_mutex_destroy(&mutexMonitor);
}

```

Thread operation for every bat:-

- arrive();

-cross();

-leave();

```

void *batOperation(void* arg){
    int i = *((int *) arg);
    bat * batObj = (bat *) malloc(sizeof(bat));
    batObj->direction = directions[i];
    batObj->index = i;
    int canArr = bat_arrive(*batObj); // check that the given direction is acceptable
    if (canArr) {
        bat_cross(*batObj);
        bat_leave(*batObj);
    }
}

```

BatManager:-

counters:-

```
//Directions counters
int crossingCounter; // deadlock counter
//queuing counter
int northCounter; // ^
int westCounter; // <
int eastCounter; // >
int southCounter; // V
int waitNorth; // count the waiting bat from North on the right
int waitSouth; // count the waiting bat from south on the right
int waitEast; // count the waiting bat from East on the right
int waitWest; // count the waiting bat from West on the right
//conditionVariables
```

Monitor Mutex :-

```
pthread_mutex_t mutexMonitor; //mutex
```

Condition Variable :-

```
//conditionVariables
pthread_cond_t NorthQueue, EastQueue, SouthQueue, WestQueue, NorthFirst, EastFirst, SouthFirst, WestFirst;
```

Bat structure :-

```
typedef struct {
    int index; //order for the input
    char direction;
} bat; //bat structure
```

Bat behaviour:-

```
int bat_arrive(bat b);
void bat_cross(bat b);
void bat_leave(bat b);
void check();
char getRight(char dir);
char getLeft(char dir);
void waitRight(char right);
void signalLeft(char left);
```

Trace an Example :-

(1)(sswwnneesswwnneessss)

```
aya@aya-Inspiron-5559:~/CLionProjects/Synchronization$ ./main
sswwnneesswwnneessss
BAT 0 from s arrives at crossing
bat 0 wait to cross from s crossing
BAT 2 from w arrives at crossing
BAT 4 from n arrives at crossing
BAT 6 from e arrives at crossing
DEADLOCK: BAT jam detected, signalling North to go
BAT 0 from s crossing
BAT 0 from s leaving crossing
bat 2 wait to cross from w crossing
BAT 1 from s arrives at crossing
BAT 2 from w crossing
BAT 2 from w leaving crossing
bat 4 wait to cross from n crossing
BAT 3 from w arrives at crossing
BAT 4 from n crossing
BAT 4 from n leaving crossing
BAT 5 from n arrives at crossing
bat 6 wait to cross from e crossing
BAT 6 from e crossing
BAT 6 from e leaving crossing
bat 1 wait to cross from s crossing
BAT 7 from e arrives at crossing
BAT 1 from s crossing
BAT 1 from s leaving crossing
bat 3 wait to cross from w crossing
BAT 8 from s arrives at crossing
BAT 3 from w crossing
BAT 3 from w leaving crossing
bat 5 wait to cross from n crossing
BAT 10 from w arrives at crossing
BAT 5 from n crossing
BAT 5 from n leaving crossing
bat 7 wait to cross from e crossing
BAT 12 from n arrives at crossing
BAT 7 from e crossing
BAT 7 from e leaving crossing
BAT 15 from e arrives at crossing
bat 8 wait to cross from s crossing
BAT 8 from s crossing
BAT 8 from s leaving crossing
BAT 9 from s arrives at crossing
```

```
a-Inspiron-5559: ~/CLionProjects/Synchronization
bat 10 wait to cross from w crossing
BAT 10 from w crossing
BAT 10 from w leaving crossing
BAT 11 from w arrives at crossing
bat 12 wait to cross from n crossing
BAT 12 from n crossing
BAT 12 from n leaving crossing
bat 15 wait to cross from e crossing
BAT 13 from n arrives at crossing
BAT 15 from e crossing
BAT 15 from e leaving crossing
bat 9 wait to cross from s crossing
BAT 14 from e arrives at crossing
BAT 9 from s crossing
BAT 9 from s leaving crossing
BAT 16 from s arrives at crossing
bat 11 wait to cross from w crossing
BAT 11 from w crossing
BAT 11 from w leaving crossing
bat 13 wait to cross from n crossing
BAT 13 from n crossing
BAT 13 from n leaving crossing
bat 14 wait to cross from e crossing
BAT 14 from e crossing
BAT 14 from e leaving crossing
bat 16 wait to cross from s crossing
BAT 16 from s crossing
BAT 16 from s leaving crossing
BAT 17 from s arrives at crossing
bat 17 wait to cross from s crossing
BAT 17 from s crossing
BAT 17 from s leaving crossing
BAT 18 from s arrives at crossing
bat 18 wait to cross from s crossing
BAT 18 from s crossing
BAT 18 from s leaving crossing
BAT 19 from s arrives at crossing
bat 19 wait to cross from s crossing
BAT 19 from s crossing
BAT 19 from s leaving crossing
```

Action	crossingCounter	southCounter	eastCounter	northCounter	westCounter	waitNorth	waitEast	waitSouth	waitWest
BAT 0 from s arrives at crossing	0	1	0	0	0	00	0	0	0
bat 0 wait to cross	1	1	0	0	0	0	00	0	0

from s crossing									
Bat4 arrive to West Line before B0 cross Enter the cross function and wait on the right South	2	1	0	0	1	0	0	0	1
Bat 5 arrive to North line Enter the cross function and wait on the right West	3	1	0	1	1	1	0	0	1
Action	crossingC ounter	southC ounter	eastCo unter	north Count er	west Coun ter	waitNor th	waitEas t	waitSouth	waitWest
Bat 6 Enter the cross function and wait on the right South	4	1	1	1	1	1	1	0	1
4 bats are in the cross section signal North	4	1	1	1	1	0	1	0	1
Bat 0 complete its crossing And signal left West	3	1	1	1	1	0	1	0	0
Bat 0 leave the crossing	3	0	1	1	1	0	1	0	0
Bat 2 cross and signal north	1	0	0	1	0	-1	1	0	0
Bat 5 sleep 1 sec to cross	1	0	0	1	0	0	1	0	1
Bat 3 w arrive	2	0	0	1	1	0	1	0	1
Bat 5 cross and signal left	1	0	0	1	1	0	0	0	0
Bat 5 leave crossing	1	0	0	0	1	0	0	0	0
Bat 6 e wait to cross and Doesn't wait on right	1	0	0	0	1	0	0	0	0
Bat 4 arrive n	2	0	0	1	1	0	0	0	0

```
i-Inspiron-5559: ~/CLionProjects/Synchronization
BAT 0 from s arrives at crossing
    northCounter = 0;
    southCounter = 1;
    eastCounter = 0;
    westCounter = 0;
    crossingCounter = 1 ;
    waitEast = 0;
    waitNorth = 0;
    waitSouth = 0;
    waitWest = 0;
----before checking---
*****Enter the cross and try to wait on the right***** northCounter = 0;
    southCounter = 1;
    eastCounter = 0;
    westCounter = 0;
    crossingCounter = 1 ;
    waitEast = 0;
    waitNorth = 0;
    waitSouth = 0;
    waitWest = 0;
bat 0 wait to cross from s crossing
BAT 4 from n arrives at crossing
    northCounter = 1;
    southCounter = 2;
    eastCounter = 0;
    westCounter = 0;
    crossingCounter = 2 ;
    waitEast = 0;
    waitNorth = 0;
    waitSouth = 0;
    waitWest = 0;
----before checking---
BAT 3 from w arrives at crossing
    northCounter = 1;
    southCounter = 2;
    eastCounter = 0;
    westCounter = 1;
    crossingCounter = 3 ;
    waitEast = 0;
    waitNorth = 0;
    waitSouth = 0;
    waitWest = 0;
----before checking---
```

```
a-Inspiron-5559: ~/CLionProjects/Synchronization
-----before checking---
BAT 6 from e arrives at crossing
northCounter = 2;
    southCounter = 2;
    eastCounter = 1;
    westCounter = 2;
    crossingCounter = 4 ;
    waitEast = 0;
    waitNorth = 1;
    waitSouth = 0;
    waitWest = 1;
-----before checking---
DEADLOCK: BAT jam detected, signalling North to go
-----Solving the DeadLock -----
northCounter = 2;
    southCounter = 2;
    eastCounter = 1;
    westCounter = 2;
    crossingCounter = 3 ;
    waitEast = 0;
    waitNorth = 1;
    waitSouth = 0;
    waitWest = 1;
BAT 0 from s crossing
*****After Crossing *****
northCounter = 4;
    southCounter = 8;
    eastCounter = 4;
    westCounter = 4;
    crossingCounter = 2 ;
    waitEast = 1;
    waitNorth = 1;
    waitSouth = 0;
    waitWest = 1;
-*-*-*-*-*Try to signal left-*-*-*-*-
northCounter = 4;
    southCounter = 8;
    eastCounter = 4;
    westCounter = 4;
    crossingCounter = 2 ;
    waitEast = 1;
    waitNorth = 1;
    waitSouth = 0;
```

```
ya-Inspiron-5559: ~/CLionProjects/Synchronization
```

```
    waitSouth = 0;
    waitWest = 0;
BAT 0 from s leaving crossing
BAT 1 from s arrives at crossing
northCounter = 4;
    southCounter = 7;
    eastCounter = 4;
    westCounter = 4;
    crossingCounter = 3 ;
    waitEast = 1;
    waitNorth = 1;
    waitSouth = 0;
    waitWest = 0;
-----before checking---
*****Enter the cross and try to wait on the right***** northCounter = 4;
    southCounter = 7;
    eastCounter = 4;
    westCounter = 4;
    crossingCounter = 3 ;
    waitEast = 1;
    waitNorth = 1;
    waitSouth = 1;
    waitWest = 0;
bat 3 wait to cross from w crossing
BAT 3 from w crossing
*****After Crossing *****
northCounter = 4;
    southCounter = 7;
    eastCounter = 4;
    westCounter = 4;
    crossingCounter = 2 ;
    waitEast = 1;
    waitNorth = 1;
    waitSouth = 1;
    waitWest = 0;
-*-*-*-*-*Try to signal left--*-*-*-*-
northCounter = 4;
    southCounter = 7;
    eastCounter = 4;
    westCounter = 4;
    crossingCounter = 2 ;
    waitEast = 1;
    waitNorth = 0;
```

```
a-Inspiron-5559: ~/CLionProjects/Synchronization
```

```
    waitWest = 0;
bat 4 wait to cross from n crossing
BAT 3 from w leaving crossing
BAT 2 from w arrives at crossing
    northCounter = 4;
        southCounter = 7;
        eastCounter = 4;
        westCounter = 3;
        crossingCounter = 3 ;
        waitEast = 1;
        waitNorth = 0;
        waitSouth = 1;
        waitWest = 0;
-----before checking---
BAT 4 from n crossing
*****After Crossing *****
northCounter = 4;
    southCounter = 7;
    eastCounter = 4;
    westCounter = 3;
    crossingCounter = 2 ;
    waitEast = 1;
    waitNorth = 0;
    waitSouth = 1;
    waitWest = 1;
-*-*-*-*-Try to signal left--*-*-*
northCounter = 4;
    southCounter = 7;
    eastCounter = 4;
    westCounter = 3;
    crossingCounter = 2 ;
    waitEast = 0;
    waitNorth = 0;
    waitSouth = 1;
    waitWest = 1;
BAT 4 from n leaving crossing
BAT 5 from n arrives at crossing
    northCounter = 3;
        southCounter = 7;
        eastCounter = 4;
        westCounter = 3;
        crossingCounter = 3 ;
        waitEast = 0;
```

```
a-Inspiron-5559: ~/CLionProjects/Synchronization
    waitNorth = 0;
    waitSouth = 1;
    waitWest = 1;
-----before checking---
*****Enter the cross and try to wait on the right***** northCounter = 3;
    southCounter = 7;
    eastCounter = 4;
    westCounter = 3;
    crossingCounter = 3 ;
    waitEast = 0;
    waitNorth = 1;
    waitSouth = 1;
    waitWest = 1;
bat 6 wait to cross from e crossing
BAT 6 from e crossing
*****After Crossing *****
northCounter = 3;
    southCounter = 7;
    eastCounter = 4;
    westCounter = 3;
    crossingCounter = 2 ;
    waitEast = 0;
    waitNorth = 1;
    waitSouth = 1;
    waitWest = 1;
-*-*-*-*-*Try to signal left---*-*-*-*-
northCounter = 3;
    southCounter = 7;
    eastCounter = 4;
    westCounter = 3;
    crossingCounter = 2 ;
    waitEast = 0;
    waitNorth = 1;
    waitSouth = 0;
    waitWest = 1;
BAT 6 from e leaving crossing
*****Enter the cross and try to wait on the right***** northCounter = 3;
    southCounter = 7;
    eastCounter = 3;
    westCounter = 3;
    crossingCounter = 2 ;
    waitEast = 0;
    waitNorth = 1;
```

```
/a-Inspiron-5559: ~/CLionProjects/Synchronization
bat 2 wait to cross from w crossing
BAT 8 from s arrives at crossing
    northCounter = 3;
    southCounter = 6;
    eastCounter = 3;
    westCounter = 3;
    crossingCounter = 3 ;
    waitEast = 1;
    waitNorth = 1;
    waitSouth = 0;
    waitWest = 0;
-----before checking---
BAT 2 from w crossing
*****After Crossing *****
    northCounter = 3;
    southCounter = 6;
    eastCounter = 3;
    westCounter = 3;
    crossingCounter = 2 ;
    waitEast = 1;
    waitNorth = 1;
    waitSouth = 1;
    waitWest = 0;
-*-*-*-*-Try to signal left--*-*-*
northCounter = 3;
    southCounter = 6;
    eastCounter = 3;
    westCounter = 3;
    crossingCounter = 2 ;
    waitEast = 1;
    waitNorth = 0;
    waitSouth = 1;
    waitWest = 0;
BAT 2 from w leaving crossing
*****Enter the cross and try to wait on the right***** northCounter = 3;
    southCounter = 6;
    eastCounter = 3;
    westCounter = 2;
    crossingCounter = 2 ;
    waitEast = 1;
    waitNorth = 0;
    waitSouth = 1;
    waitWest = 0;
```

```
a-Inspiron-5559: ~/CLionProjects/Synchronization
```

```
bat 5 wait to cross from n crossing
BAT 11 from w arrives at crossing
northCounter = 3;
    southCounter = 6;
    eastCounter = 3;
    westCounter = 2;
    crossingCounter = 3 ;
    waitEast = 1;
    waitNorth = 0;
    waitSouth = 1;
    waitWest = 0;
-----before checking---
BAT 5 from n crossing
*****After Crossing *****
northCounter = 3;
    southCounter = 6;
    eastCounter = 3;
    westCounter = 2;
    crossingCounter = 2 ;
    waitEast = 1;
    waitNorth = 0;
    waitSouth = 1;
    waitWest = 1;
-*.*-*-*-*Try to signal left--*-*-*-*-
northCounter = 3;
    southCounter = 6;
    eastCounter = 3;
    westCounter = 2;
    crossingCounter = 2 ;
    waitEast = 0;
    waitNorth = 0;
    waitSouth = 1;
    waitWest = 1;
BAT 5 from n leaving crossing
BAT 12 from n arrives at crossing
northCounter = 2;
    southCounter = 6;
    eastCounter = 3;
    westCounter = 2;
    crossingCounter = 3 ;
    waitEast = 0;
    waitNorth = 0;
    waitSouth = 1;
```

```
a-Inspiron-5559: ~/CLionProjects/Synchronization
----before checking---
*****Enter the cross and try to wait on the right***** northCounter = 2;
southCounter = 6;
eastCounter = 3;
westCounter = 2;
crossingCounter = 3 ;
waitEast = 0;
waitNorth = 1;
waitSouth = 1;
waitWest = 1;
bat 7 wait to cross from e crossing
BAT 7 from e crossing
*****After Crossing *****
northCounter = 2;
southCounter = 6;
eastCounter = 3;
westCounter = 2;
crossingCounter = 2 ;
waitEast = 0;
waitNorth = 1;
waitSouth = 1;
waitWest = 1;
-*-*-*-*-*Try to signal left--*-*-*-*-
northCounter = 2;
southCounter = 6;
eastCounter = 3;
westCounter = 2;
crossingCounter = 2 ;
waitEast = 0;
waitNorth = 1;
waitSouth = 0;
waitWest = 1;
BAT 7 from e leaving crossing
*****Enter the cross and try to wait on the right***** northCounter = 2;
southCounter = 6;
eastCounter = 2;
westCounter = 2;
crossingCounter = 2 ;
waitEast = 0;
waitNorth = 1;
waitSouth = 0;
waitWest = 1;
BAT 14 from e arrives at crossing
```

```
a-Inspiron-5559: ~/CLionProjects/Synchronization
northCounter = 2;
southCounter = 6;
eastCounter = 2;
westCounter = 2;
crossingCounter = 3 ;
waitEast = 0;
waitNorth = 1;
waitSouth = 0;
waitWest = 1;
-----before checking---
bat 8 wait to cross from s crossing
BAT 8 from s crossing
*****After Crossing *****
northCounter = 2;
southCounter = 6;
eastCounter = 2;
westCounter = 2;
crossingCounter = 2 ;
waitEast = 1;
waitNorth = 1;
waitSouth = 0;
waitWest = 1;
-*-*-*-*-*Try to signal left--*-*-*-*-
northCounter = 2;
southCounter = 6;
eastCounter = 2;
westCounter = 2;
crossingCounter = 2 ;
waitEast = 1;
waitNorth = 1;
waitSouth = 0;
waitWest = 0;
*****Enter the cross and try to wait on the right***** northCounter = 2;
southCounter = 6;
eastCounter = 2;
westCounter = 2;
crossingCounter = 2 ;
waitEast = 1;
waitNorth = 1;
waitSouth = 0;
waitWest = 0;
bat 11 wait to cross from w crossing
BAT 8 from s leaving crossing
```

```
-Inspiron-5559: ~/CLionProjects/Synchronization
BAT 9 from s arrives at crossing
    northCounter = 2;
    southCounter = 5;
    eastCounter = 2;
    westCounter = 2;
    crossingCounter = 3 ;
    waitEast = 1;
    waitNorth = 1;
    waitSouth = 0;
    waitWest = 0;
-----before checking---
BAT 11 from w crossing
*****After Crossing *****
    northCounter = 2;
    southCounter = 5;
    eastCounter = 2;
    westCounter = 2;
    crossingCounter = 2 ;
    waitEast = 1;
    waitNorth = 1;
    waitSouth = 1;
    waitWest = 0;
-*-*-*-*Try to signal left-*-*-*-*-
    northCounter = 2;
    southCounter = 5;
    eastCounter = 2;
    westCounter = 2;
    crossingCounter = 2 ;
    waitEast = 1;
    waitNorth = 0;
    waitSouth = 1;
    waitWest = 0;
BAT 11 from w leaving crossing
*****Enter the cross and try to wait on the right***** northCounter = 2;
    southCounter = 5;
    eastCounter = 2;
    westCounter = 1;
    crossingCounter = 2 ;
    waitEast = 1;
    waitNorth = 0;
    waitSouth = 1;
    waitWest = 0;
bat 12 wait to cross from n crossing
```

```
a-Inspiron-5559: ~/CLionProjects/Synchronization
```

```
BAT 10 from w arrives at crossing
    northCounter = 2;
        southCounter = 5;
        eastCounter = 2;
        westCounter = 1;
        crossingCounter = 3 ;
        waitEast = 1;
        waitNorth = 0;
        waitSouth = 1;
        waitWest = 0;
-----before checking---
BAT 12 from n crossing
*****After Crossing *****
    northCounter = 2;
        southCounter = 5;
        eastCounter = 2;
        westCounter = 1;
        crossingCounter = 2 ;
        waitEast = 1;
        waitNorth = 0;
        waitSouth = 1;
        waitWest = 1;
-*-*-*-*-*Try to signal left--*-*-*-*-
    northCounter = 2;
        southCounter = 5;
        eastCounter = 2;
        westCounter = 1;
        crossingCounter = 2 ;
        waitEast = 0;
        waitNorth = 0;
        waitSouth = 1;
        waitWest = 1;
BAT 12 from n leaving crossing
BAT 13 from n arrives at crossing
    northCounter = 1;
        southCounter = 5;
        eastCounter = 2;
        westCounter = 1;
        crossingCounter = 3 ;
        waitEast = 0;
        waitNorth = 0;
        waitSouth = 1;
        waitWest = 1;
```

```
a-Inspiron-5559: ~/CLionProjects/Synchronization
-----before checking---
*****Enter the cross and try to wait on the right***** northCounter = 1;
    southCounter = 5;
    eastCounter = 2;
    westCounter = 1;
    crossingCounter = 3 ;
    waitEast = 0;
    waitNorth = 1;
    waitSouth = 1;
    waitWest = 1;
bat 14 wait to cross from e crossing
BAT 14 from e crossing
*****After Crossing *****
northCounter = 1;
    southCounter = 5;
    eastCounter = 2;
    westCounter = 1;
    crossingCounter = 2 ;
    waitEast = 0;
    waitNorth = 1;
    waitSouth = 1;
    waitWest = 1;
-*-*-*-*-*Try to signal left--*-*-*-*-
northCounter = 1;
    southCounter = 5;
    eastCounter = 2;
    westCounter = 1;
    crossingCounter = 2 ;
    waitEast = 0;
    waitNorth = 1;
    waitSouth = 0;
    waitWest = 1;
BAT 14 from e leaving crossing
BAT 15 from e arrives at crossing
northCounter = 1;
    southCounter = 5;
    eastCounter = 1;
    westCounter = 1;
    crossingCounter = 3 ;
    waitEast = 0;
    waitNorth = 1;
    waitSouth = 0;
    waitWest = 1;
```

```
a-Inspiron-5559: ~/CLionProjects/Synchronization
-----before checking---
*****Enter the cross and try to wait on the right***** northCounter = 1;
    southCounter = 5;
    eastCounter = 1;
    westCounter = 1;
    crossingCounter = 3 ;
    waitEast = 1;
    waitNorth = 1;
    waitSouth = 0;
    waitWest = 1;
bat 9 wait to cross from s crossing
BAT 9 from s crossing
*****After Crossing *****
    northCounter = 1;
    southCounter = 5;
    eastCounter = 1;
    westCounter = 1;
    crossingCounter = 2 ;
    waitEast = 1;
    waitNorth = 1;
    waitSouth = 0;
    waitWest = 1;
-**-*-*-*-*Try to signal left--*-*-*-*-
    northCounter = 1;
    southCounter = 5;
    eastCounter = 1;
    westCounter = 1;
    crossingCounter = 2 ;
    waitEast = 1;
    waitNorth = 1;
    waitSouth = 0;
    waitWest = 0;
BAT 9 from s leaving crossing
BAT 16 from s arrives at crossing
    northCounter = 1;
    southCounter = 4;
    eastCounter = 1;
    westCounter = 1;
    crossingCounter = 3 ;
    waitEast = 1;
    waitNorth = 1;
    waitSouth = 0;
    waitWest = 0;
```

```
ya-Inspiron-5559: ~/CLionProjects/Synchronization
-----before checking---
*****Enter the cross and try to wait on the right***** northCounter = 1;
    southCounter = 4;
    eastCounter = 1;
    westCounter = 1;
    crossingCounter = 3 ;
    waitEast = 1;
    waitNorth = 1;
    waitSouth = 1;
    waitWest = 0;
bat 10 wait to cross from w crossing
BAT 10 from w crossing
*****After Crossing *****
    northCounter = 1;
    southCounter = 4;
    eastCounter = 1;
    westCounter = 1;
    crossingCounter = 2 ;
    waitEast = 1;
    waitNorth = 1;
    waitSouth = 1;
    waitWest = 0;
-*-*-*-*-*Try to signal left--*-*-*-*-
    northCounter = 1;
    southCounter = 4;
    eastCounter = 1;
    westCounter = 1;
    crossingCounter = 2 ;
    waitEast = 1;
    waitNorth = 0;
    waitSouth = 1;
    waitWest = 0;
BAT 10 from w leaving crossing
*****Enter the cross and try to wait on the right***** northCounter = 1;
    southCounter = 4;
    eastCounter = 1;
    westCounter = 0;
    crossingCounter = 2 ;
    waitEast = 1;
    waitNorth = 0;
    waitSouth = 1;
    waitWest = 0;
bat 13 wait to cross from n crossing
```

```
/a-Inspiron-5559: ~/CLionProjects/Synchronization
BAT 13 from n crossing
*****After Crossing *****
northCounter = 1;
southCounter = 4;
eastCounter = 1;
westCounter = 0;
crossingCounter = 1 ;
waitEast = 1;
waitNorth = 0;
waitSouth = 1;
waitWest = 0;
-*-*-*-*-*Try to signal left--*-*-*-*-
northCounter = 1;
southCounter = 4;
eastCounter = 1;
westCounter = 0;
crossingCounter = 1 ;
waitEast = 0;
waitNorth = 0;
waitSouth = 1;
waitWest = 0;
BAT 13 from n leaving crossing
*****Enter the cross and try to wait on the right***** northCounter = 0;
southCounter = 4;
eastCounter = 1;
westCounter = 0;
crossingCounter = 1 ;
waitEast = 0;
waitNorth = 0;
waitSouth = 1;
waitWest = 0;
bat 15 wait to cross from e crossing
BAT 15 from e crossing
*****After Crossing *****
northCounter = 0;
southCounter = 4;
eastCounter = 1;
westCounter = 0;
crossingCounter = 0 ;
waitEast = 0;
waitNorth = 0;
waitSouth = 1;
waitWest = 0;
```

```
a-Inspiron-5559: ~/CLionProjects/Synchronization
-*-*-*-Try to signal left--*-*-*
northCounter = 0;
southCounter = 4;
eastCounter = 1;
westCounter = 0;
crossingCounter = 0 ;
waitEast = 0;
waitNorth = 0;
waitSouth = 0;
waitWest = 0;
BAT 15 from e leaving crossing
*****Enter the cross and try to wait on the right***** northCounter = 0;
southCounter = 4;
eastCounter = 0;
westCounter = 0;
crossingCounter = 0 ;
waitEast = 0;
waitNorth = 0;
waitSouth = 0;
waitWest = 0;
bat 16 wait to cross from s crossing
BAT 16 from s crossing
*****After Crossing *****
northCounter = 0;
southCounter = 4;
eastCounter = 0;
westCounter = 0;
crossingCounter = -1 ;
waitEast = 0;
waitNorth = 0;
waitSouth = 0;
waitWest = 0;
-*-*-*-Try to signal left--*-*-*
northCounter = 0;
southCounter = 4;
eastCounter = 0;
westCounter = 0;
crossingCounter = -1 ;
waitEast = 0;
waitNorth = 0;
waitSouth = 0;
waitWest = 0;
BAT 16 from s leaving crossing
```

```
a-Inspiron-5559: ~/CLionProjects/Synchronization
bat 16 wait to cross from s crossing
BAT 16 from s crossing
*****After Crossing *****
northCounter = 0;
    southCounter = 4;
    eastCounter = 0;
    westCounter = 0;
    crossingCounter = -1 ;
    waitEast = 0;
    waitNorth = 0;
    waitSouth = 0;
    waitWest = 0;
-*-*-*-*-*Try to signal left--*-*-*-*-
northCounter = 0;
    southCounter = 4;
    eastCounter = 0;
    westCounter = 0;
    crossingCounter = -1 ;
    waitEast = 0;
    waitNorth = 0;
    waitSouth = 0;
    waitWest = 0;
BAT 16 from s leaving crossing
BAT 17 from s arrives at crossing
northCounter = 0;
    southCounter = 3;
    eastCounter = 0;
    westCounter = 0;
    crossingCounter = 0 ;
    waitEast = 0;
    waitNorth = 0;
    waitSouth = 0;
    waitWest = 0;
----before checking---
*****Enter the cross and try to wait on the right***** northCounter = 0;
    southCounter = 3;
    eastCounter = 0;
    westCounter = 0;
    crossingCounter = 0 ;
    waitEast = 0;
    waitNorth = 0;
    waitSouth = 0;
    waitWest = 0;
```

```
a-Inspiron-5559: ~/CLionProjects/Synchronization
bat 17 wait to cross from s crossing
BAT 17 from s crossing
*****After Crossing *****
northCounter = 0;
    southCounter = 3;
    eastCounter = 0;
    westCounter = 0;
    crossingCounter = -1 ;
    waitEast = 0;
    waitNorth = 0;
    waitSouth = 0;
    waitWest = 0;
-*-*-*-*-*Try to signal left--*-*-*-*-
northCounter = 0;
    southCounter = 3;
    eastCounter = 0;
    westCounter = 0;
    crossingCounter = -1 ;
    waitEast = 0;
    waitNorth = 0;
    waitSouth = 0;
    waitWest = 0;
BAT 17 from s leaving crossing
BAT 18 from s arrives at crossing
northCounter = 0;
    southCounter = 2;
    eastCounter = 0;
    westCounter = 0;
    crossingCounter = 0 ;
    waitEast = 0;
    waitNorth = 0;
    waitSouth = 0;
    waitWest = 0;
-----before checking---
*****Enter the cross and try to wait on the right***** northCounter = 0;
    southCounter = 2;
    eastCounter = 0;
    westCounter = 0;
    crossingCounter = 0 ;
    waitEast = 0;
    waitNorth = 0;
    waitSouth = 0;
    waitWest = 0;
```

```
a-Inspiron-5559: ~/CLionProjects/Synchronization
bat 18 wait to cross from s crossing
BAT 18 from s crossing
*****After Crossing *****
northCounter = 0;
    southCounter = 2;
    eastCounter = 0;
    westCounter = 0;
    crossingCounter = -1 ;
    waitEast = 0;
    waitNorth = 0;
    waitSouth = 0;
    waitWest = 0;
-*-*-*-*Try to signal left--*-*-*-*-
northCounter = 0;
    southCounter = 2;
    eastCounter = 0;
    westCounter = 0;
    crossingCounter = -1 ;
    waitEast = 0;
    waitNorth = 0;
    waitSouth = 0;
    waitWest = 0;
BAT 18 from s leaving crossing
BAT 19 from s arrives at crossing
    northCounter = 0;
        southCounter = 1;
        eastCounter = 0;
        westCounter = 0;
        crossingCounter = 0 ;
        waitEast = 0;
        waitNorth = 0;
        waitSouth = 0;
        waitWest = 0;
-----before checking---
*****Enter the cross and try to wait on the right***** northCounter = 0;
    southCounter = 1;
    eastCounter = 0;
    westCounter = 0;
    crossingCounter = 0 ;
    waitEast = 0;
    waitNorth = 0;
    waitSouth = 0;
    waitWest = 0;
```

```
aya-Inspiron-5559: ~/CLionProjects/Synchronization
    northCounter = 0;
    southCounter = 1;
    eastCounter = 0;
    westCounter = 0;
    crossingCounter = 0 ;
    waitEast = 0;
    waitNorth = 0;
    waitSouth = 0;
    waitWest = 0;
    -----before checking---
*****Enter the cross and try to wait on the right***** northCounter = 0;
    southCounter = 1;
    eastCounter = 0;
    westCounter = 0;
    crossingCounter = 0 ;
    waitEast = 0;
    waitNorth = 0;
    waitSouth = 0;
    waitWest = 0;
bat 19 wait to cross from s crossing
BAT 19 from s crossing
*****After Crossing *****
    northCounter = 0;
    southCounter = 1;
    eastCounter = 0;
    westCounter = 0;
    crossingCounter = -1 ;
    waitEast = 0;
    waitNorth = 0;
    waitSouth = 0;
    waitWest = 0;
-*-*-*-*-*Try to signal left-*-*-*-*-
    northCounter = 0;
    southCounter = 1;
    eastCounter = 0;
    westCounter = 0;
    crossingCounter = -1 ;
    waitEast = 0;
    waitNorth = 0;
    waitSouth = 0;
    waitWest = 0;
BAT 19 from s leaving crossing
aya@aya-Inspiron-5559:~/CLionProjects/Synchronization$ ^[[2~_
```

SnapShot :-

```
aya@aya-Inspiron-5559:~/CLionProjects/Synchronization$ ./main
nsewwewn
BAT 0 from n arrives at crossing
bat 0 wait to cross from n crossing
BAT 6 from w arrives at crossing
bat 6 wait to cross from w crossing
BAT 5 from e arrives at crossing
BAT 1 from s arrives at crossing
DEADLOCK: BAT jam detected, signalling North to go
BAT 0 from n crossing
BAT 0 from n leaving crossing
BAT 7 from n arrives at crossing
bat 5 wait to cross from e crossing
BAT 6 from w crossing
BAT 6 from w leaving crossing
BAT 4 from w arrives at crossing
bat 7 wait to cross from n crossing
BAT 5 from e crossing
BAT 5 from e leaving crossing
BAT 2 from e arrives at crossing
BAT 7 from n crossing
BAT 7 from n leaving crossing
bat 1 wait to cross from s crossing
bat 2 wait to cross from e crossing
BAT 1 from s crossing
BAT 1 from s leaving crossing
bat 4 wait to cross from w crossing
BAT 2 from e crossing
BAT 2 from e leaving crossing
BAT 4 from w crossing
BAT 4 from w leaving crossing
BAT 3 from w arrives at crossing
bat 3 wait to cross from w crossing
BAT 3 from w crossing
BAT 3 from w leaving crossing
```

```
[1]: Stopped      ./main
aya@aya-Inspiron-5559:~/CLionProjects/Synchronization$ ./main
nnnnwwwweeee
BAT 6 from w arrives at crossing
BAT 8 from e arrives at crossing
BAT 3 from n arrives at crossing
BAT 6 from w crossing
BAT 6 from w leaving crossing
BAT 8 from e crossing
BAT 8 from e leaving crossing
BAT 7 from w arrives at crossing
BAT 9 from e arrives at crossing
BAT 3 from n crossing
BAT 3 from n leaving crossing
BAT 2 from n arrives at crossing
BAT 7 from w crossing
BAT 7 from w leaving crossing
BAT 5 from w arrives at crossing
BAT 9 from e crossing
BAT 9 from e leaving crossing
BAT 10 from e arrives at crossing
BAT 2 from n crossing
BAT 2 from n leaving crossing
BAT 1 from n arrives at crossing
BAT 5 from w crossing
BAT 5 from w leaving crossing
BAT 4 from w arrives at crossing
BAT 4 from w crossing
BAT 4 from w leaving crossing
BAT 10 from e crossing
BAT 10 from e leaving crossing
BAT 11 from e arrives at crossing
BAT 1 from n crossing
BAT 1 from n leaving crossing
BAT 0 from n arrives at crossing
BAT 11 from e crossing
BAT 11 from e leaving crossing
BAT 0 from n crossing
BAT 0 from n leaving crossing
```

```
[1]: Stopped      ./main
aya@aya-Inspiron-5559:~/CLionProjects/Synchronization$ ./main
a
You enter wrong direction
aya@aya-Inspiron-5559:~/CLionProjects/Synchronization$ _
```

Example(2) :-

Wewewewewesnsnsnsn

ya-Inspiron-5559: ~/CLionProjects/Synchronization

```
wewewewesnsnsnsn  
BAT 0 from w arrives at crossing  
bat 0 wait to cross from w crossing  
BAT 1 from e arrives at crossing  
bat 1 wait to cross from e crossing  
BAT 14 from s arrives at crossing  
BAT 13 from n arrives at crossing  
DEADLOCK: BAT jam detected, signalling North to go  
BAT 0 from w crossing  
BAT 0 from w leaving crossing  
BAT 2 from w arrives at crossing  
BAT 1 from e crossing  
BAT 1 from e leaving crossing  
BAT 3 from e arrives at crossing  
bat 14 wait to cross from s crossing  
bat 13 wait to cross from n crossing  
BAT 14 from s crossing  
bat 2 wait to cross from w crossing  
BAT 14 from s leaving crossing  
BAT 12 from s arrives at crossing  
BAT 13 from n crossing  
BAT 13 from n leaving crossing  
BAT 17 from n arrives at crossing  
bat 3 wait to cross from e crossing  
BAT 2 from w crossing  
BAT 2 from w leaving crossing  
BAT 4 from w arrives at crossing  
bat 17 wait to cross from n crossing  
BAT 3 from e crossing  
BAT 3 from e leaving crossing  
bat 12 wait to cross from s crossing  
BAT 5 from e arrives at crossing  
BAT 17 from n crossing  
BAT 17 from n leaving crossing  
BAT 11 from n arrives at crossing  
bat 5 wait to cross from e crossing  
BAT 12 from s crossing  
bat 4 wait to cross from w crossing  
BAT 12 from s leaving crossing  
BAT 16 from s arrives at crossing  
BAT 5 from e crossing  
BAT 5 from e leaving crossing  
BAT 9 from e arrives at crossing
```

```
BAT 5 from e crossing
BAT 5 from e leaving crossing
BAT 9 from e arrives at crossing
BAT 4 from w crossing
BAT 4 from w leaving crossing
BAT 6 from w arrives at crossing
bat 16 wait to cross from s crossing
bat 11 wait to cross from n crossing
BAT 16 from s crossing
BAT 16 from s leaving crossing
BAT 10 from s arrives at crossing
BAT 11 from n crossing
BAT 11 from n leaving crossing
bat 6 wait to cross from w crossing
BAT 15 from n arrives at crossing
bat 9 wait to cross from e crossing
BAT 9 from e crossing
BAT 9 from e leaving crossing
bat 10 wait to cross from s crossing
BAT 7 from e arrives at crossing
BAT 6 from w crossing
bat 15 wait to cross from n crossing
BAT 6 from w leaving crossing
BAT 8 from w arrives at crossing
BAT 10 from s crossing
BAT 10 from s leaving crossing
BAT 18 from s arrives at crossing
bat 8 wait to cross from w crossing
BAT 15 from n crossing
BAT 15 from n leaving crossing
BAT 19 from n arrives at crossing
bat 7 wait to cross from e crossing
BAT 8 from w crossing
BAT 8 from w leaving crossing
bat 19 wait to cross from n crossing
BAT 7 from e crossing
BAT 7 from e leaving crossing
bat 18 wait to cross from s crossing
BAT 18 from s crossing
BAT 18 from s leaving crossing
BAT 19 from n crossing
BAT 19 from n leaving crossing
zhu@zhu-Japonica-5559:~/ClientProjects/Synchronization$
```

Example (3):

Wwwswwwwwwnnnnnneeeee

```
-Inspiron-5559: ~/CLionProjects/Synchronization
```

```
WWWSWWWWWWNNNNnneeee  
BAT 5 from w arrives at crossing  
bat 5 wait to cross from w crossing  
BAT 3 from s arrives at crossing  
bat 3 wait to cross from s crossing  
BAT 10 from n arrives at crossing  
BAT 15 from e arrives at crossing  
DEADLOCK: BAT jam detected, signalling North to go  
BAT 5 from w crossing  
BAT 5 from w leaving crossing  
BAT 1 from w arrives at crossing  
BAT 3 from s crossing  
bat 10 wait to cross from n crossing  
BAT 3 from s leaving crossing  
bat 1 wait to cross from w crossing  
BAT 10 from n crossing  
BAT 10 from n leaving crossing  
BAT 11 from n arrives at crossing  
bat 15 wait to cross from e crossing  
BAT 1 from w crossing  
BAT 1 from w leaving crossing  
BAT 7 from w arrives at crossing  
bat 7 wait to cross from w crossing  
bat 11 wait to cross from n crossing  
BAT 15 from e crossing  
BAT 15 from e leaving crossing  
BAT 16 from e arrives at crossing  
BAT 11 from n crossing  
BAT 11 from n leaving crossing  
BAT 12 from n arrives at crossing  
bat 16 wait to cross from e crossing  
BAT 7 from w crossing  
BAT 7 from w leaving crossing  
bat 12 wait to cross from n crossing  
BAT 0 from w arrives at crossing  
bat 0 wait to cross from w crossing  
BAT 16 from e crossing  
BAT 16 from e leaving crossing  
BAT 0 from w crossing  
BAT 17 from e arrives at crossing  
BAT 12 from n crossing  
BAT 0 from w leaving crossing  
BAT 4 from w arrives at crossing
```

```
aya@Inspiron-5559:~/CLionProjects/Synchronization
```

```
BAT 12 from n crossing
BAT 0 from w leaving crossing
BAT 4 from w arrives at crossing
bat 4 wait to cross from w crossing
BAT 12 from n leaving crossing
BAT 13 from n arrives at crossing
bat 17 wait to cross from e crossing
BAT 4 from w crossing
bat 13 wait to cross from n crossing
BAT 4 from w leaving crossing
BAT 2 from w arrives at crossing
bat 2 wait to cross from w crossing
BAT 17 from e crossing
BAT 17 from e leaving crossing
BAT 18 from e arrives at crossing
BAT 13 from n crossing
BAT 13 from n leaving crossing
BAT 14 from n arrives at crossing
BAT 2 from w crossing
BAT 2 from w leaving crossing
BAT 6 from w arrives at crossing
bat 6 wait to cross from w crossing
bat 14 wait to cross from n crossing
bat 18 wait to cross from e crossing
BAT 6 from w crossing
BAT 18 from e crossing
BAT 18 from e leaving crossing
BAT 19 from e arrives at crossing
BAT 14 from n crossing
BAT 14 from n leaving crossing
bat 19 wait to cross from e crossing
BAT 6 from w leaving crossing
BAT 8 from w arrives at crossing
bat 8 wait to cross from w crossing
BAT 8 from w crossing
BAT 8 from w leaving crossing
BAT 9 from w arrives at crossing
bat 9 wait to cross from w crossing
BAT 19 from e crossing
BAT 19 from e leaving crossing
BAT 9 from w crossing
BAT 9 from w leaving crossing
```

```
aya@aya-Inspiron-5559:~/CLionProjects/Synchronization$ _
```