1. Parallelization

(a) Identify the loop carried dependencies in the following code segment.

```c
for(i=0;i < N;i++) // Initialization
    a[i] = 3*i + 5*i*i;

for(t=1; t < NT; t++) // Iterative computation
    for(i=1; i < N-1; i++)
        a[i] = a[i-1] + a[i+1];
```

A) The iterative computation has a loop carried dependency. The value \( a[i] \) needs \( a[i-1] \), which is updated at previous loop.

(b) Parallelize the loop on a CREW PRAM, introducing \texttt{forall} loops where appropriate, that utilize \( O(N) \) processors.

A) The idea is having another array that has the same size with array \( A \) and copying back and forth.

```c
forall(i=0;i < N;i++) // Initialization
    a[i] = 3*i + 5*i*i;

for(t=1; t < NT; t++){ // Iterative computation
    forall(i=1; i < N-1; i++)
        if(t%2 == 0)
            b[i] = a[i-1] + a[i+1];
        else
            a[i] = b[i-1] + b[i+1];
}
```

2. Interconnect

(a) What is the diameter and bisection bandwidth of an \( N \times N \times N \) toroidal mesh interconnect?

A) Diameter: \( 3N/2 \)
   
   Bisection bandwidth: \( 2N^2 \)

(b) Give an efficient broadcast algorithm for the 3D toroidal mesh. What is the running time of your algorithm?

A) Brief description:
   - Broadcast to a one row
   - Each node that has the value broadcasts to a orthogonal row
   - The plane that has the value broadcasts to other planes.
Let assume Node (0,0,0) broadcast a value.

```plaintext
broadcastOneRow((0, 0, 0), (N-1, 0, 0));
forall(i = 0; i < N; i++)
    broadcastOneRow((i, 0, 0), (i, N-1, 0);

forall(i = 0; i < N; i++)
    forall(j = 0; j < N; j++)
        broadcastOneRow((i, j, 0), (i, j, N-1));
```

Each broadcastOneRow() takes $N/2$ time steps because propagating to both right and left direction saves $N/2$ steps Therefore, the total running time of the algorithm is $3N/2$, which is $O(N)$. 