5 Interconnection Networks [90 points]

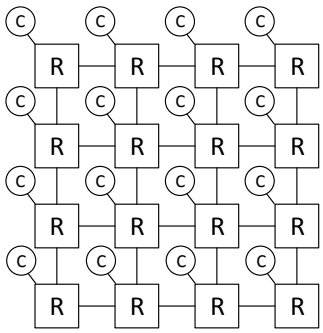
Suppose you would like to connect 2^N processors, and you are considering four different topologies:

- $\sqrt{2^N} \times \sqrt{2^N}$ 2D mesh
- $\sqrt{2^{N-2}} \times \sqrt{2^{N-2}}$ 2D concentrated mesh (Cmesh), where each router serves four processors
- $\sqrt{2^N} \times \sqrt{2^N}$ 2D torus
- Hypercube

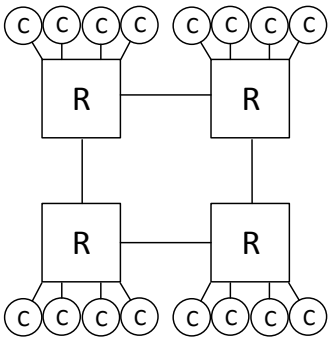
Please answer the following questions. Show your work.

(a) [20 points] For N = 4, please draw how each network looks like. You can use ... (three dots) to avoid repeated patterns.

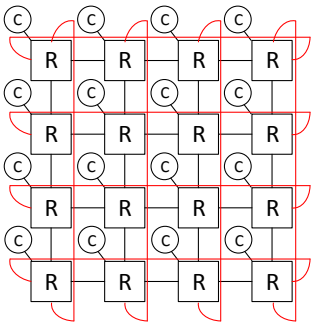
2D mesh



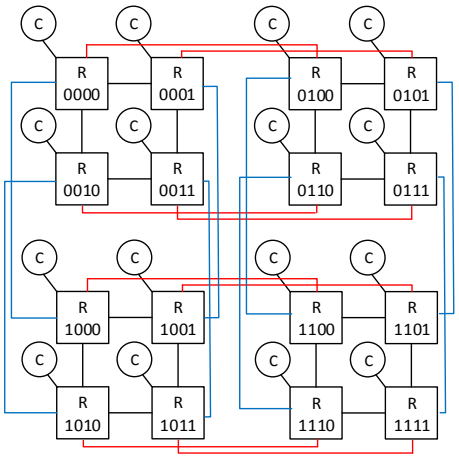
Cmesh



2D torus



Hypercube



For the remaining questions, *assume N = 8*.

(b) [20 points] For N = 8, calculate the number of network links for each network. (Hint: a single network link is bi-directional)

2D mesh: $2 \times (\sqrt{2^N} - 1)(\sqrt{2^N})$ links $\rightarrow 2 \times 15 \times 16 = 480$ links
Cmesh: $2 \times (\sqrt{2^{N-2}} - 1)(\sqrt{2^{N-2}})$ links $\rightarrow 2 \times 7 \times 8 = 112$ links
2D torus: $2 \times (\sqrt{2^N})(\sqrt{2^N})$ links $\rightarrow 2 \times 16 \times 16 = 512$ links
Hypercube: $2^N \times N/2$ links $\rightarrow 256 \times 8/2 = 1024$ links

(c) [25 points] For N = 8, calculate the number of input/output ports including the injection/ejection ports for *each router* in these topologies (Hint: give answer to all types of routers that exist in an irregular network).

2D mesh: (4+1) inputs/outputs, (3+1) inputs/outputs, and (2+1) inputs/outputs
Cmesh: (4+4) inputs/outputs, (3+4) inputs/outputs, and (2+4) inputs/outputs
2D torus: (4+1) inputs/outputs
Hypercube: N+1 inputs/outputs $\rightarrow$ 9 inputs/outputs

(d) [25 points] Assume a network link can be faulty. For each topology, what is the minimum possible number of faulty links that are needed to make at least one processor unreachable from any other processor?

2D mesh: 2 links
Cmesh: 2 links
2D torus: 4 links
Hypercube: $Nlinks \rightarrow 8$ links