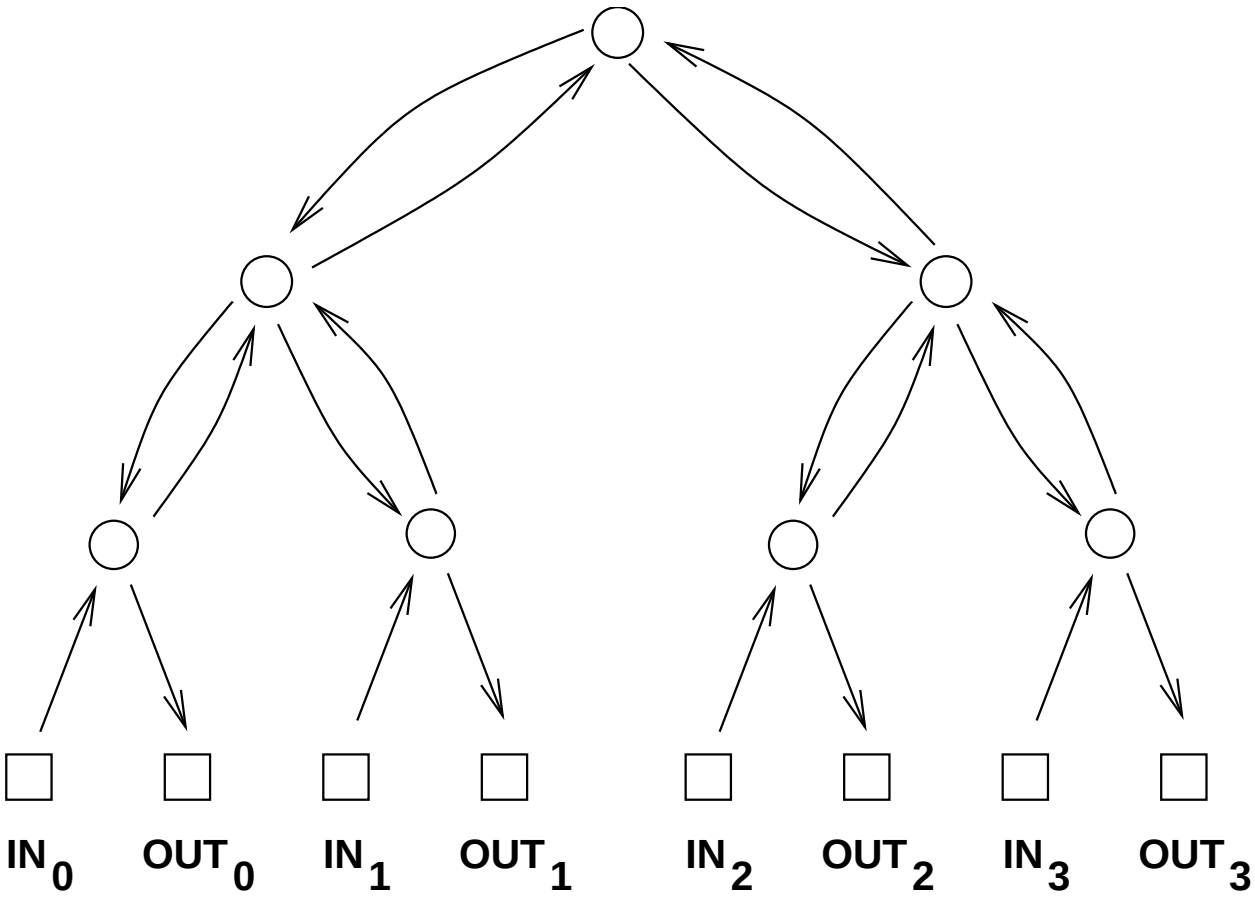
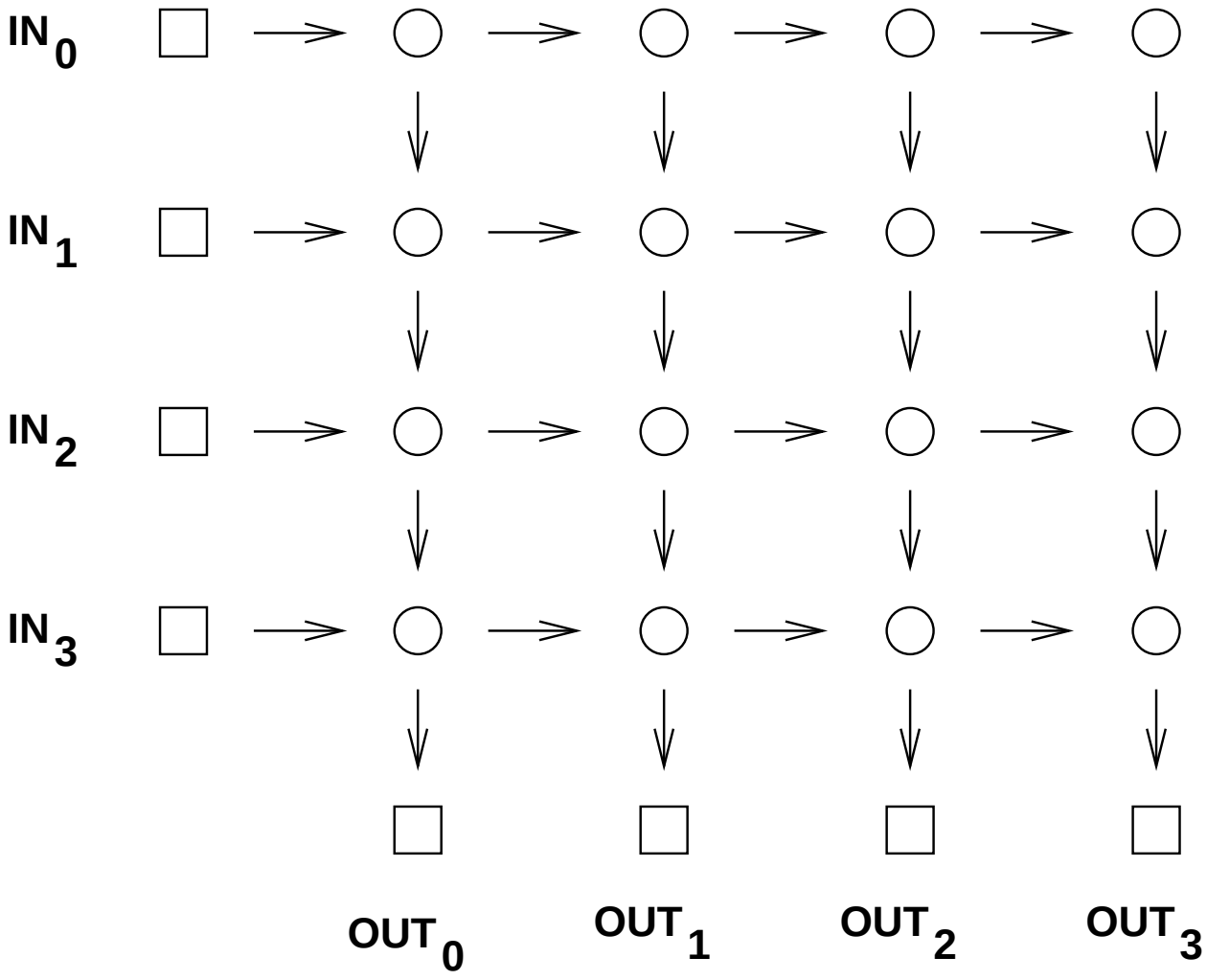
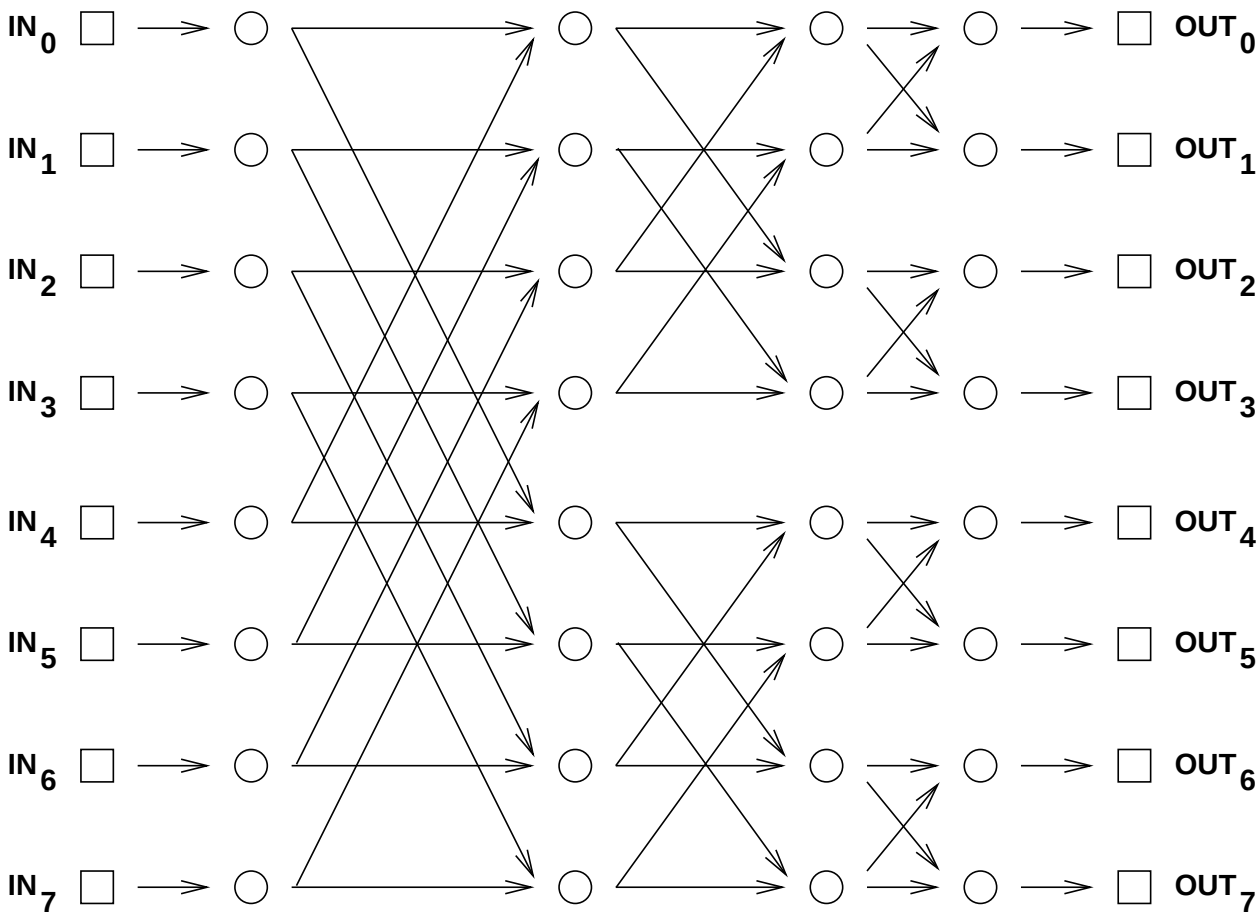
**Complete Binary Tree** $(\mathbf{N} = 4)$



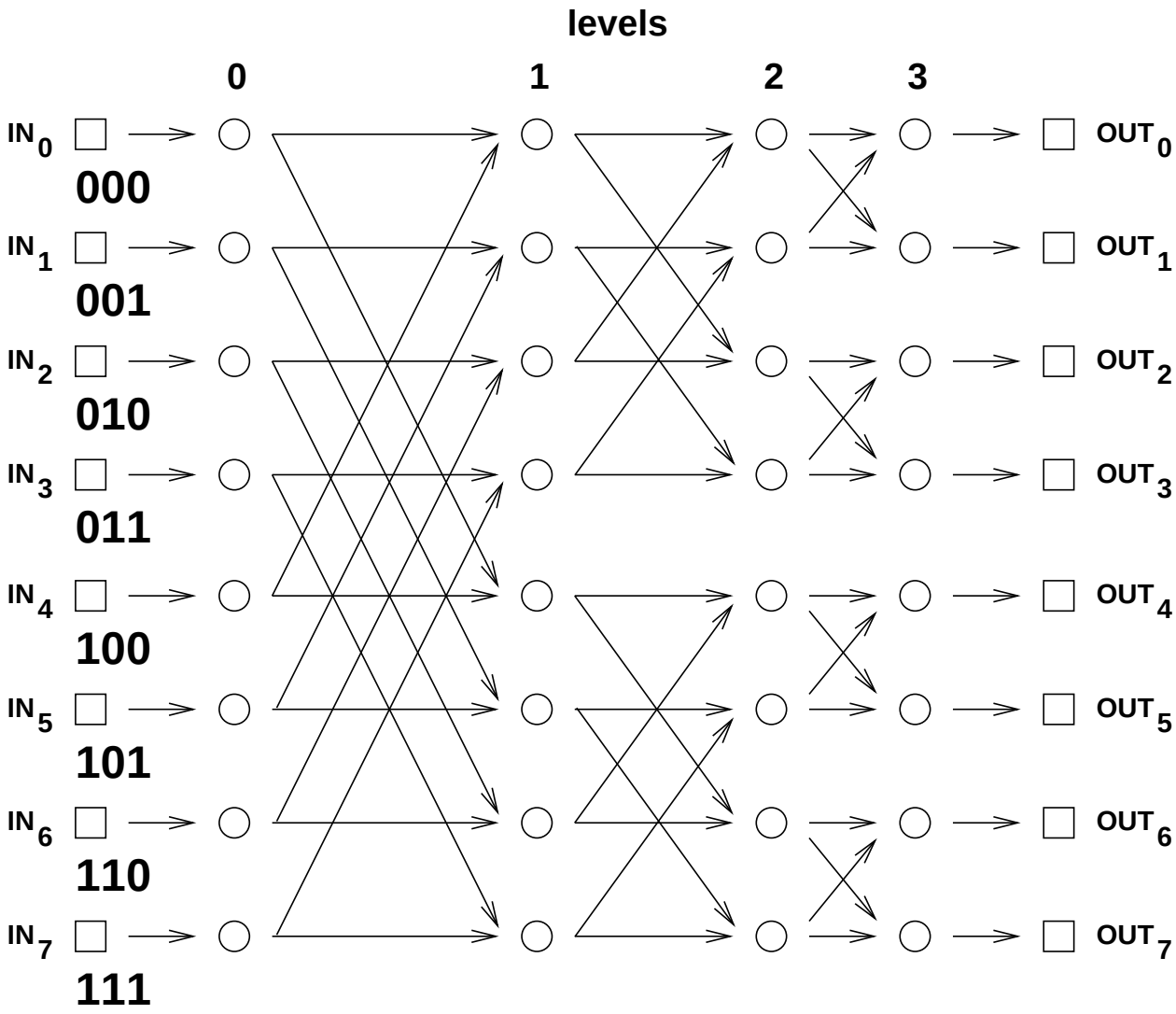
**Two-Dimenional Array** $(\mathrm{N} = 4)$
(a.k.a. Grid, Crossbar)



# Butterfly $(\mathrm{N} = 8)$



## Butterfly $(\mathrm{N} = 8)$




Nodes:

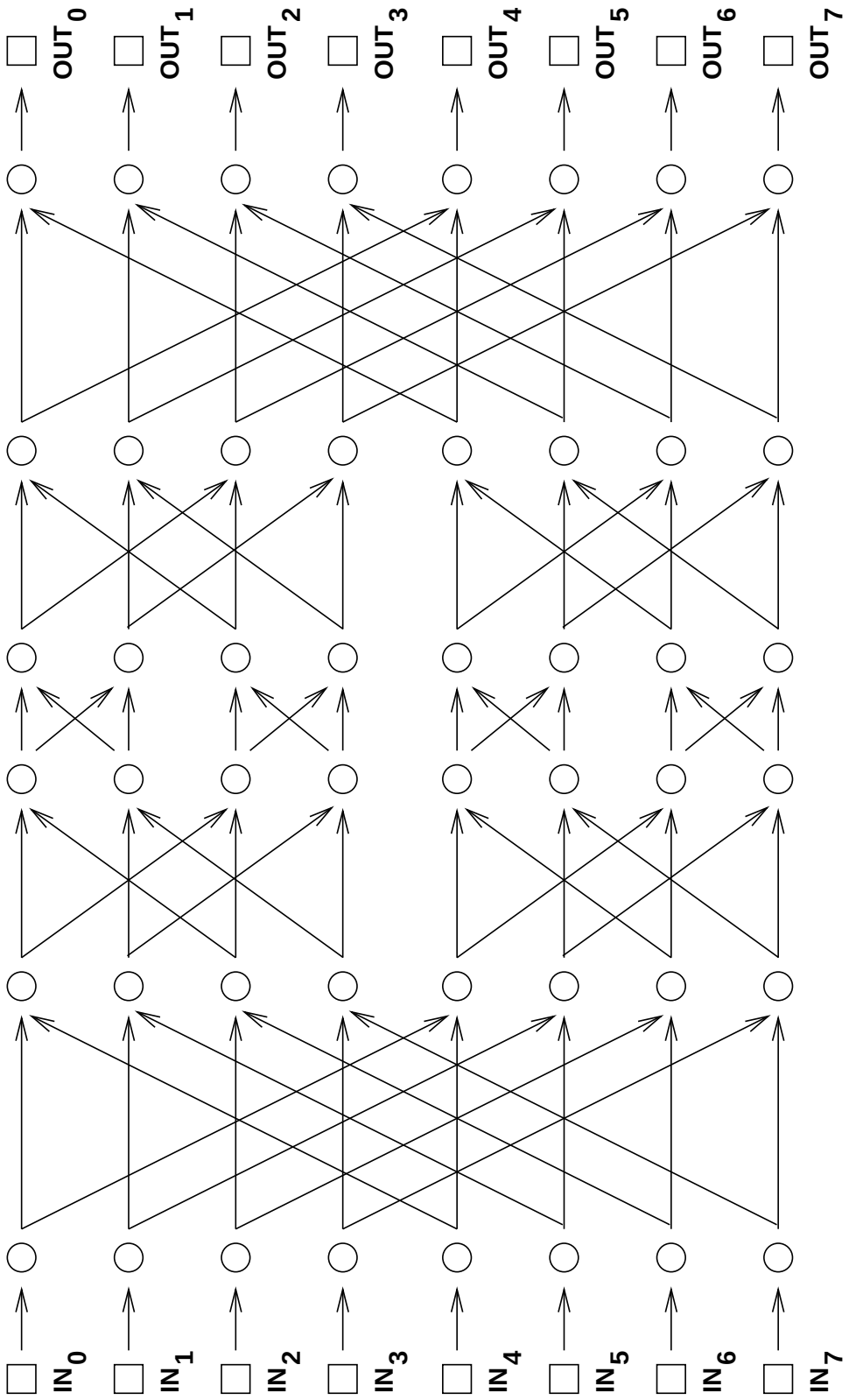
$$\{(b_1, b_2, \ldots, b_{\log N}, l) \mid b_i = 0 \text{ or } 1, 0 \leq l \leq \log N\}$$

Edges:

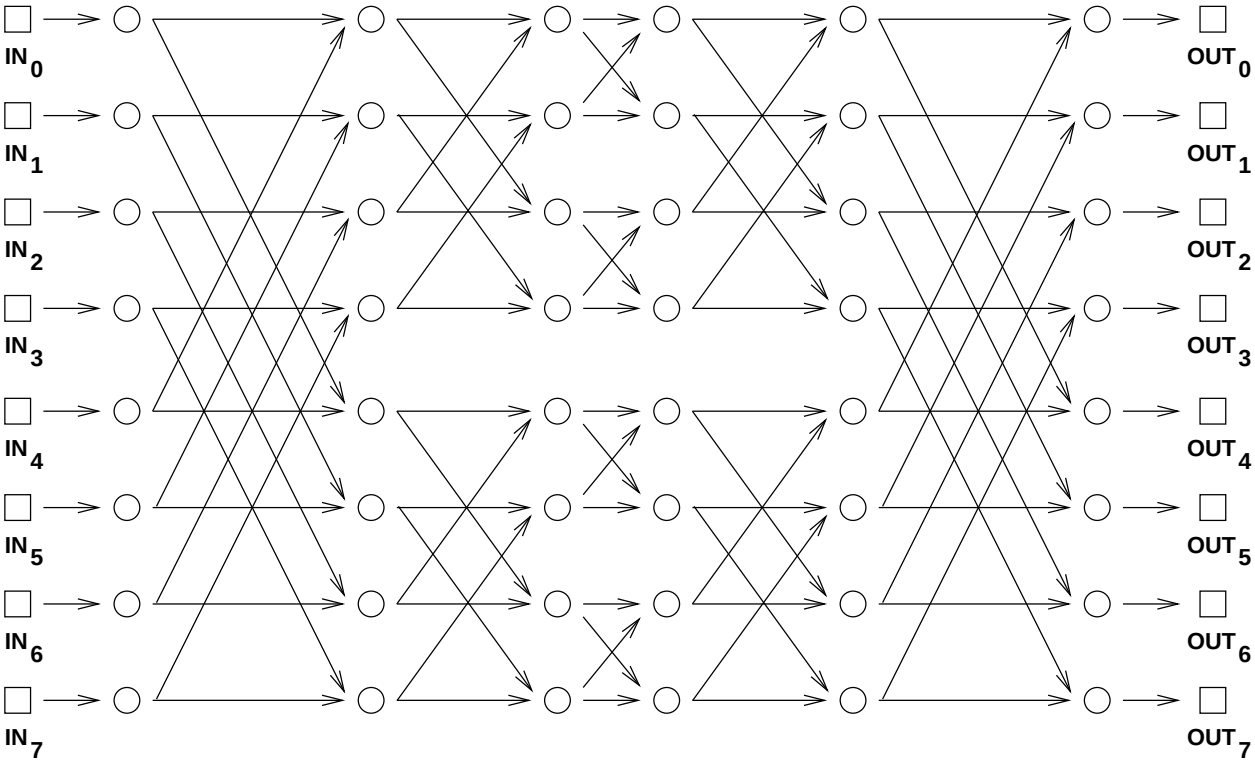
$$(b_1, b_2, \ldots, b_{\log N}, l) \nearrow (b_1, \ldots, b_{l+1}, \ldots, b_{\log N}, l+1)$$

$$(b_1, b_2, \ldots, b_{\log N}, l) \searrow (b_1, \ldots, \overline{b_{l+1}}, \ldots, b_{\log N}, l+1)$$

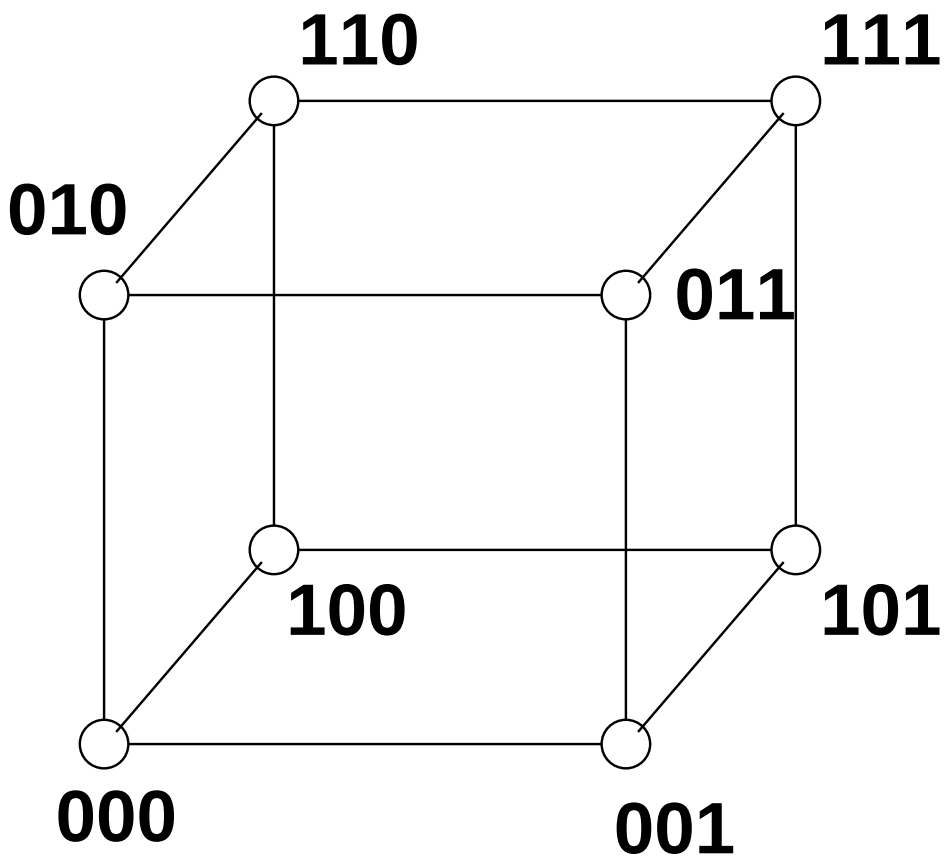
# Beneš network $(\mathrm{N} = 8)$



# Beneš network $(\mathrm{N} = 8)$



**Hypercube** $(\mathrm{N} = 8)$



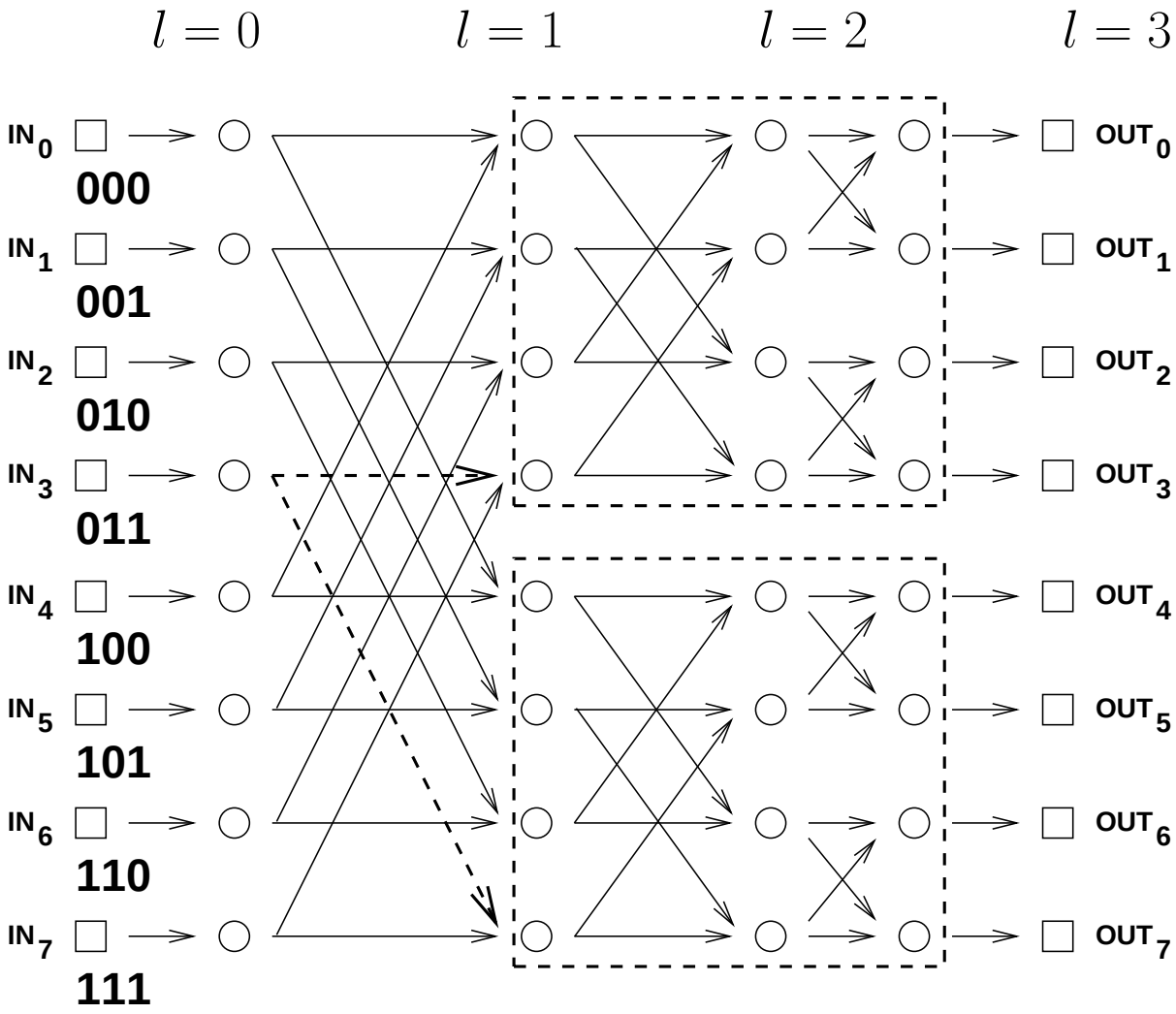

Nodes:

$$\{(b_1, b_2, \ldots, b_{\log N}) \mid b_i = 0 \text{ or } 1\}$$

Edges:

$$\{((a_1, \ldots, a_{\log N}), (b_1, \ldots, b_{\log N})) \mid$$
$$\vec{a} \text{ and } \vec{b} \text{ differ in precisely one bit}\}$$

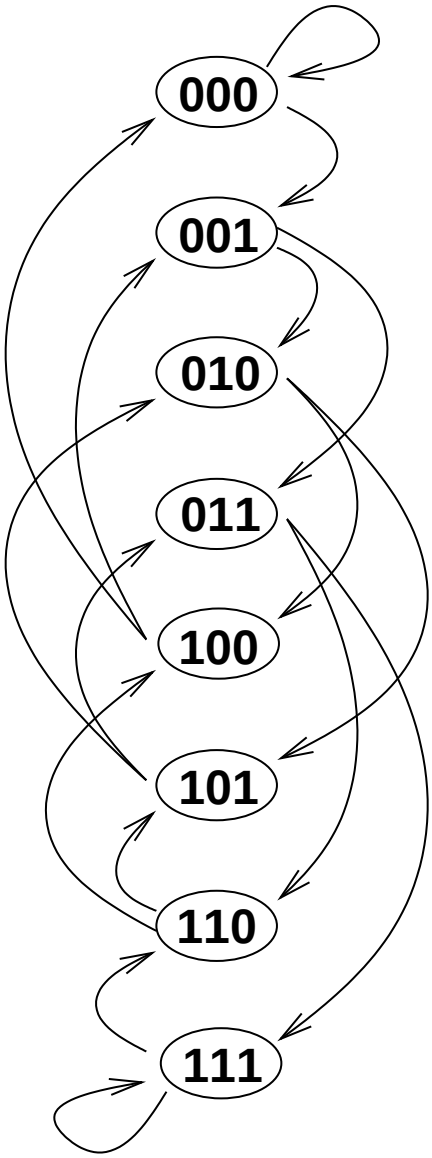
## Butterfly (redrawn)




Node $(b_1, b_2, \ldots, b_{\log N}, l)$ has been drawn in row:

$$b_{l+1}, b_{l+2}, \ldots, b_{\log N}, b_1, \ldots, b_l$$

## De Bruijn Graph $(\mathbf{N = 8})$



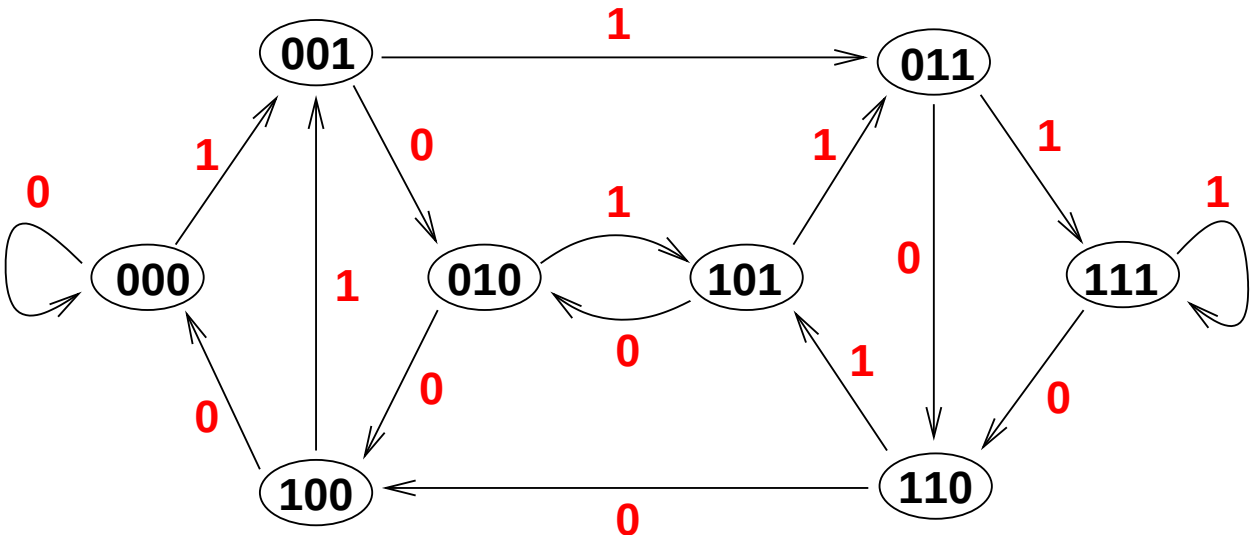

Nodes: $\{(b_1, b_2, \ldots, b_{\log N}) \mid b_i = 0 \text{ or } 1\}$

Edges:

$$(b_1, b_2, \ldots, b_{\log N}) \nearrow (b_2, \ldots, b_{\log N}, 0)$$

$$(b_1, b_2, \ldots, b_{\log N}) \searrow (b_2, \ldots, b_{\log N}, 1)$$

## De Bruijn Graph (redrawn)




Edges labels:

$$(b_1, b_2, \ldots, b_{\log N}) \xrightarrow{0} (b_2, \ldots, b_{\log N}, 0)$$

$$(b_1, b_2, \ldots, b_{\log N}) \xrightarrow{1} (b_2, \ldots, b_{\log N}, 1)$$