# Quantum error correction using belief propagation

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# Motivation:
# What is quantum error correction? Why are we doing it?

**Aim:** scalable quantum computers.

**2 solutions:**

- Better hardware
- Error correction using software

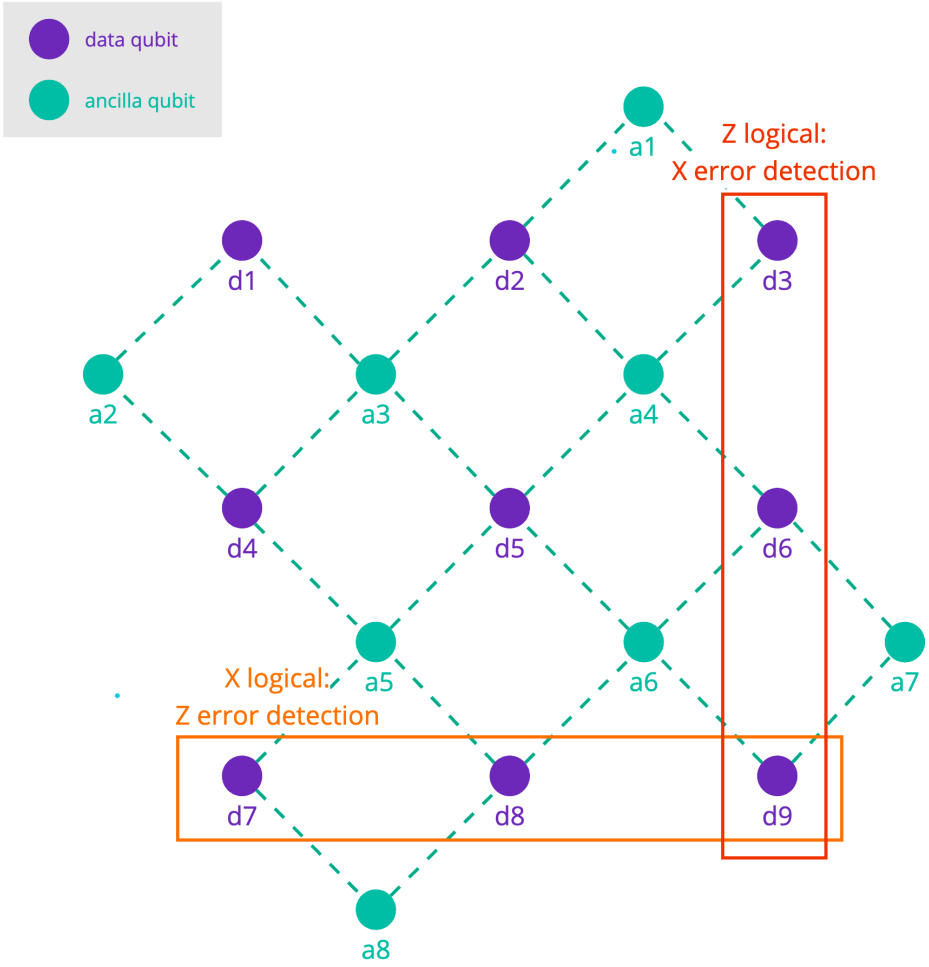



Figure: Surface code - most common quantum error correction code

# Classical error correction

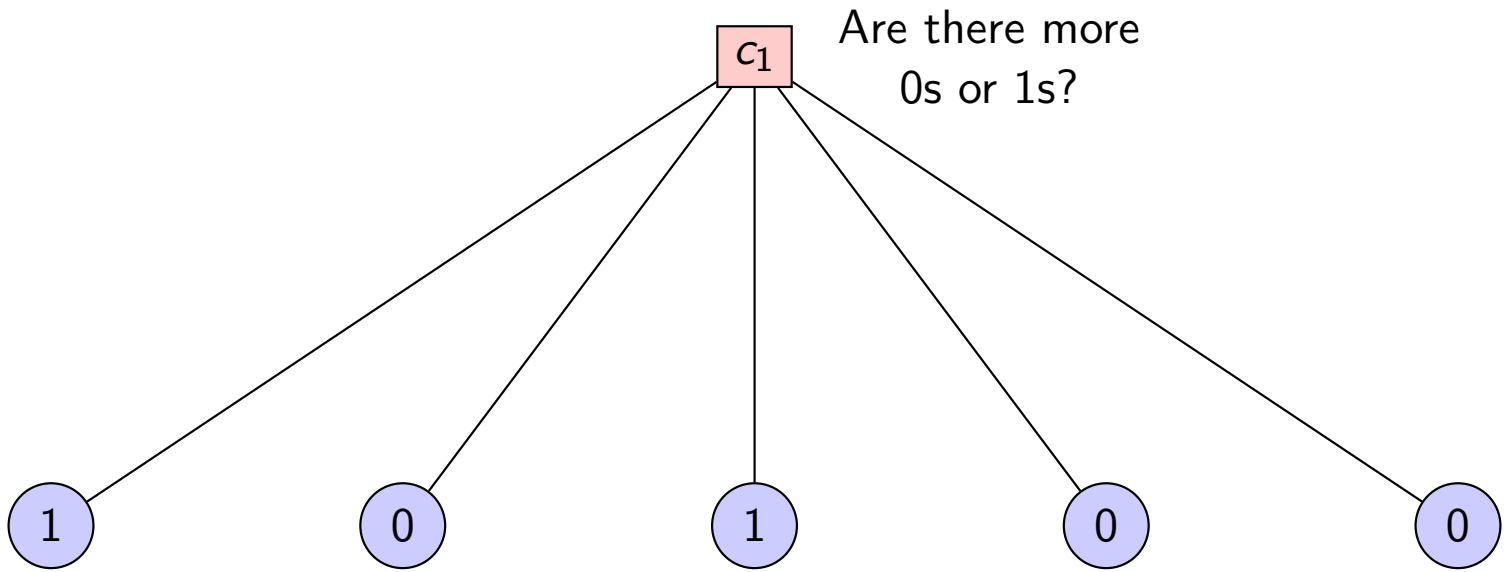
Classical error correction is a family of algorithms which reduce the probability of logical error during communication.

The simplest example: repetition code.

want to send: **0** $\longrightarrow$ repetition: **00000** $\longrightarrow$ imperfect channel: **10100**

# Repetition code

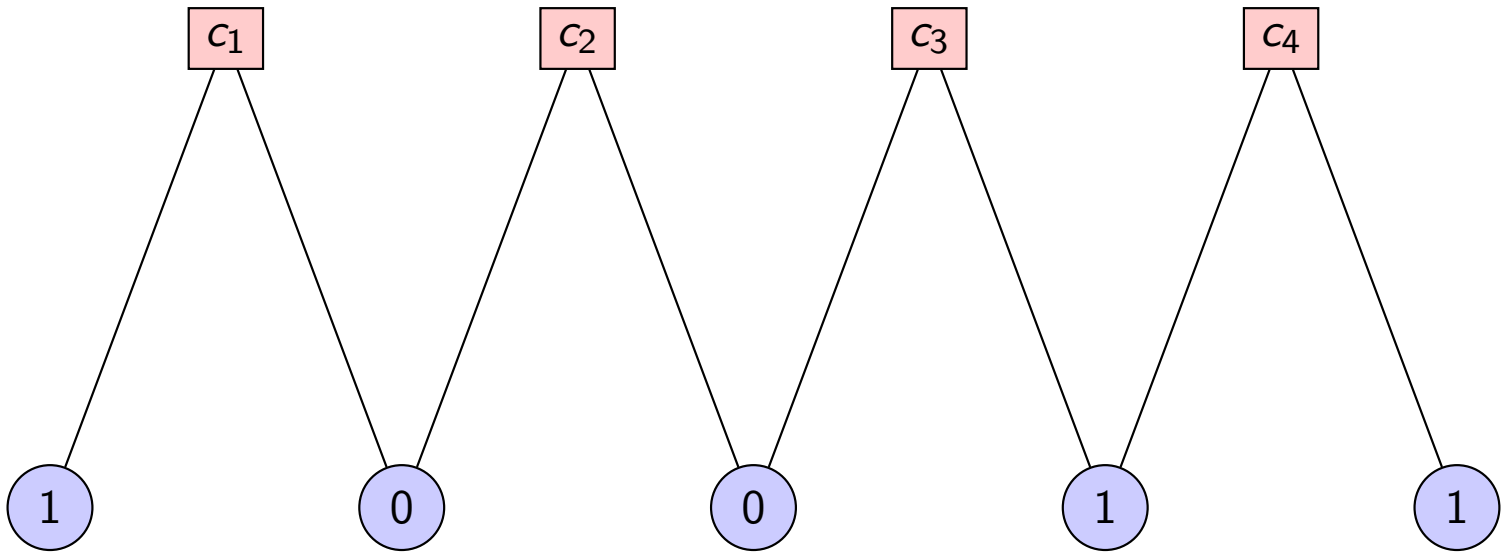
**Idea:** check all nodes, decide by majority.



# Parity check code

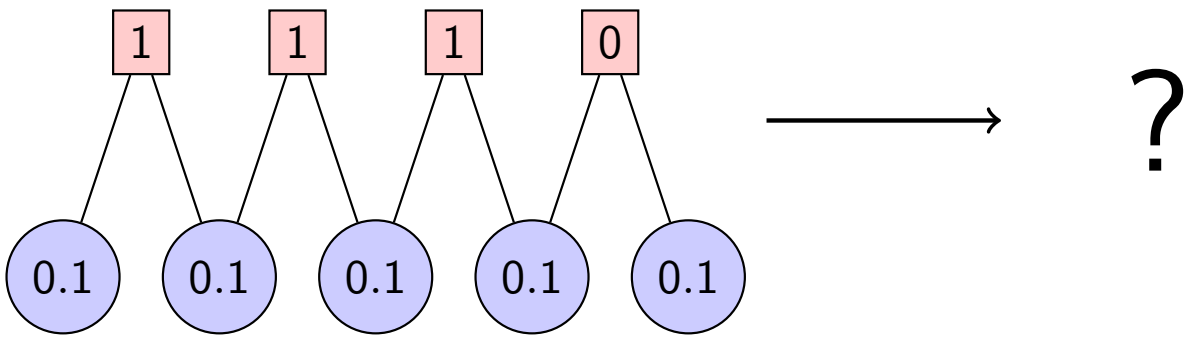
Idea: check neighbouring nodes, see if they are the same.

Are my neighbours different?

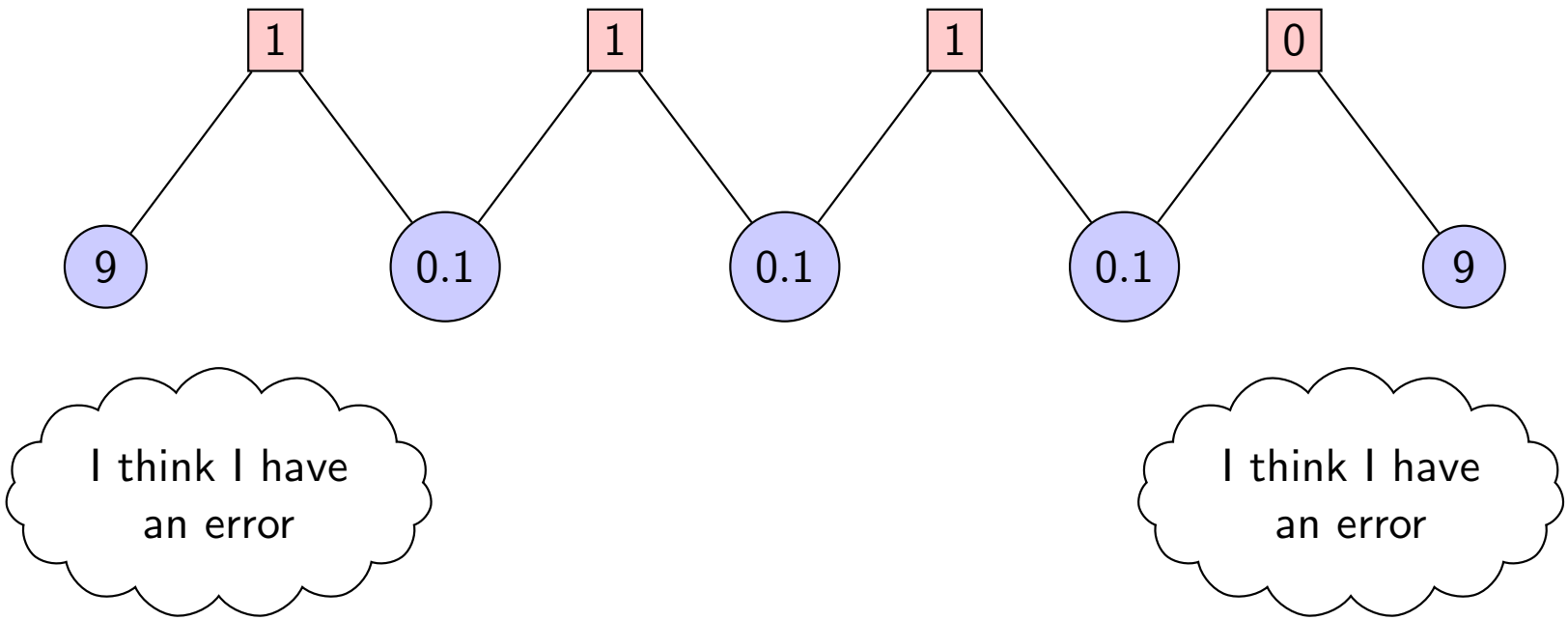


# Belief Propagation

Belief propagation is an algorithm based on Bayesian probability.
**Input:** prior probabilities of each error, values of checks.
**Output:** posterior probabilities of each error.



# Belief propagation: iterations



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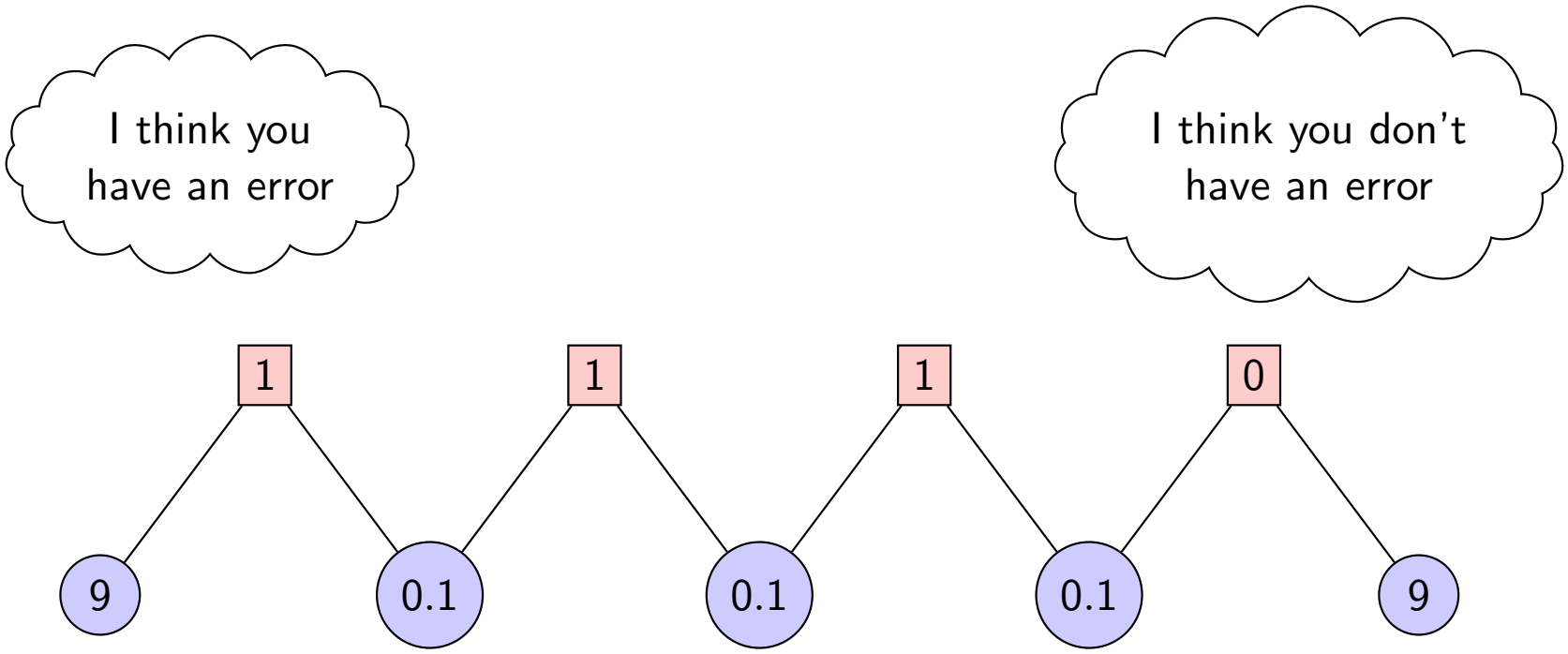

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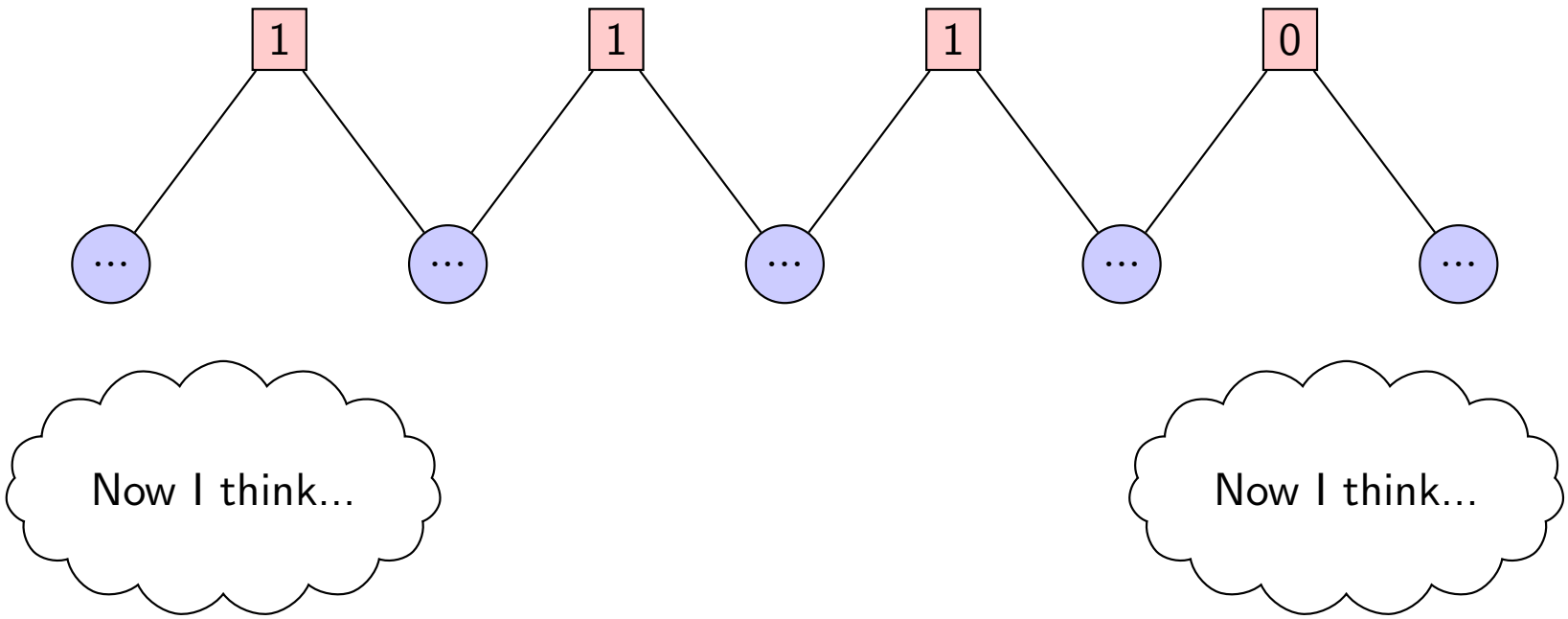

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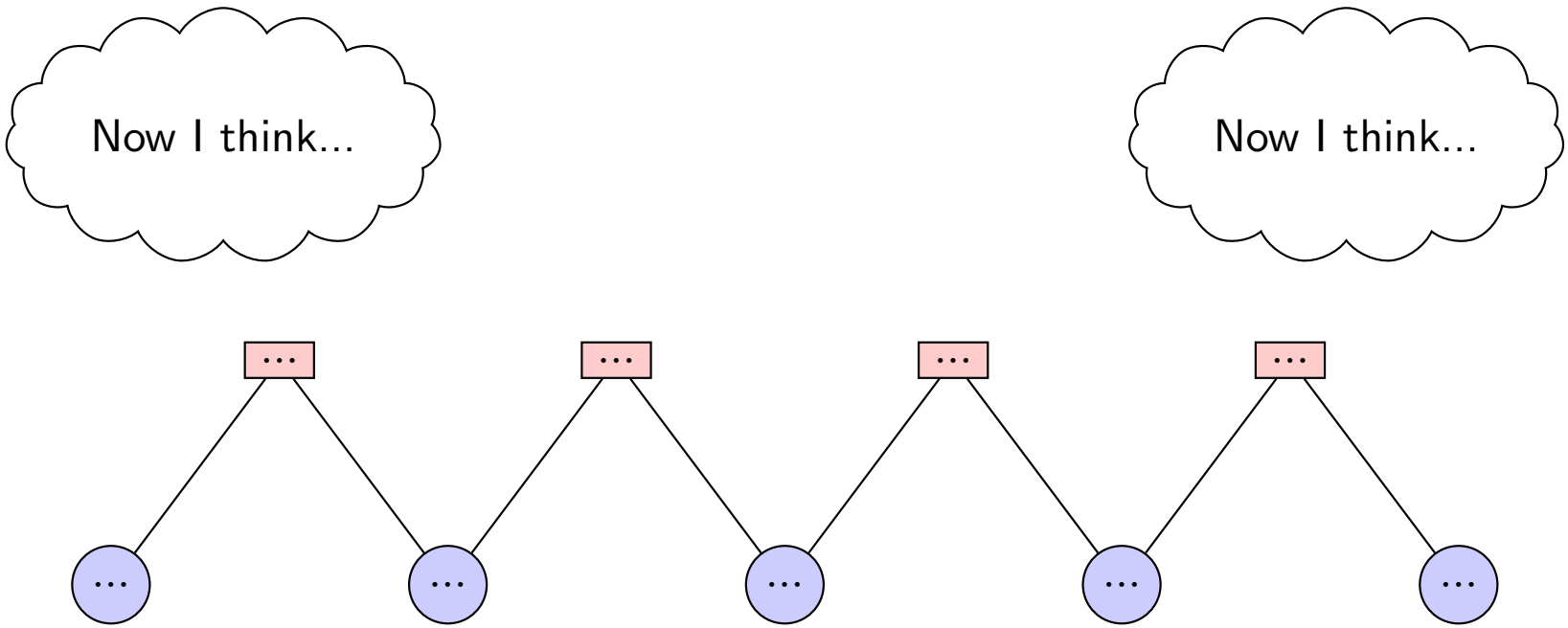

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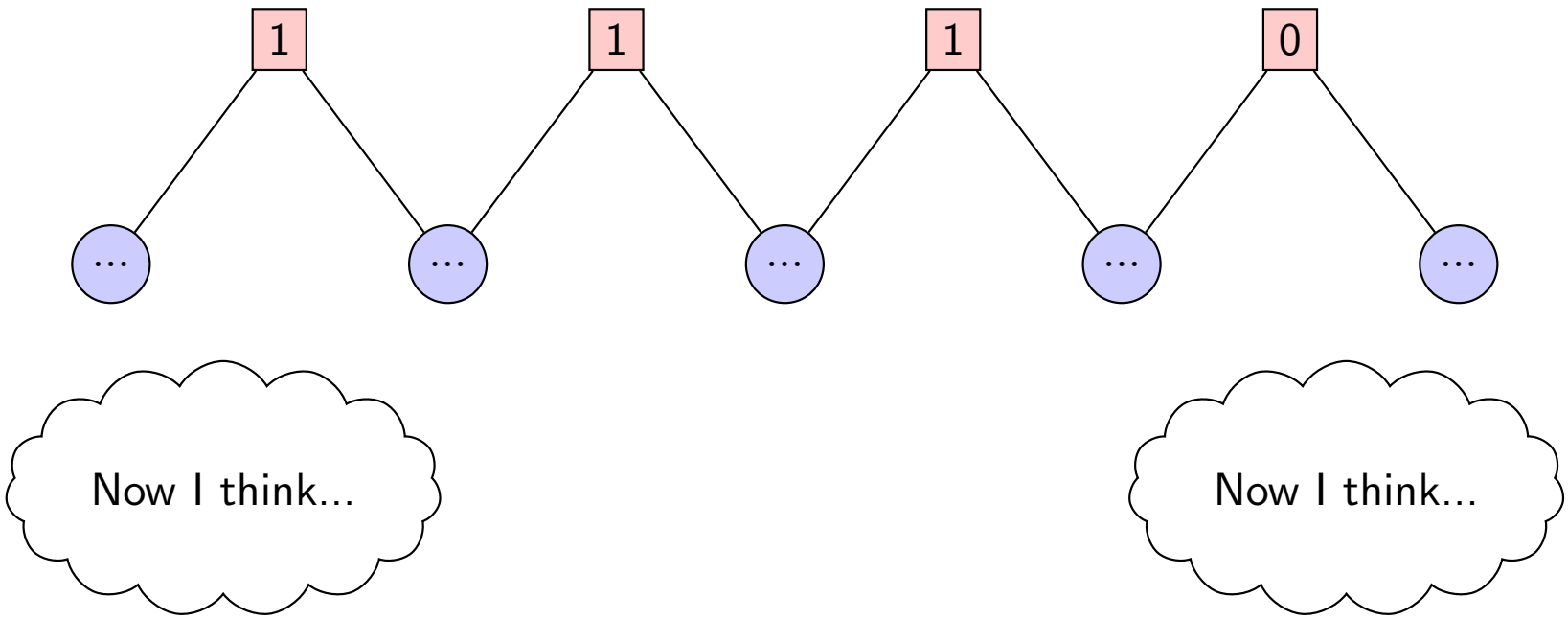

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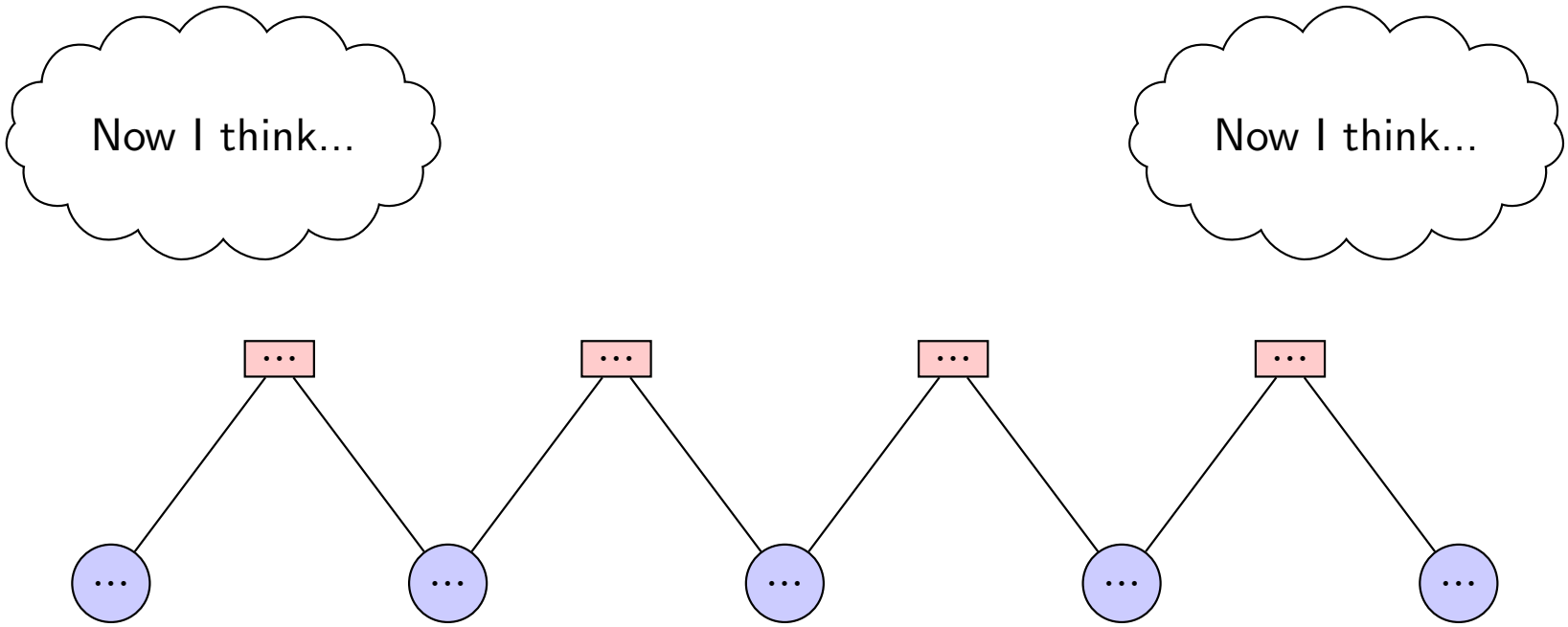
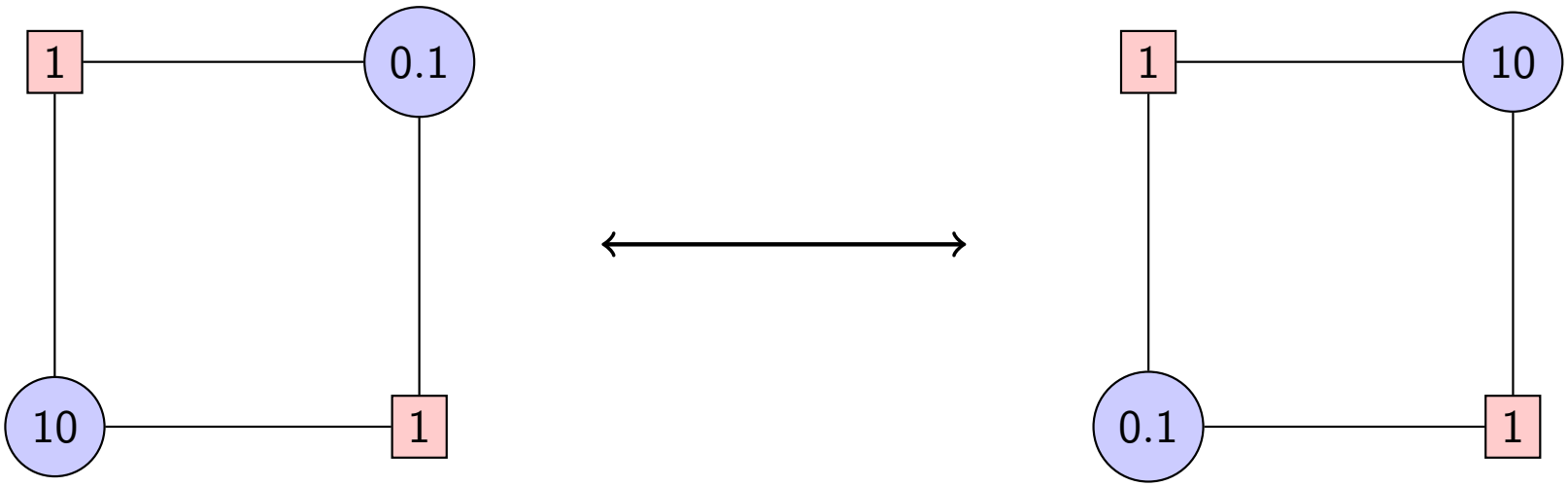



Works on trees, but what about cycles?

# Belief propagation on cyclic graphs



# Seeing cyclicity in real data

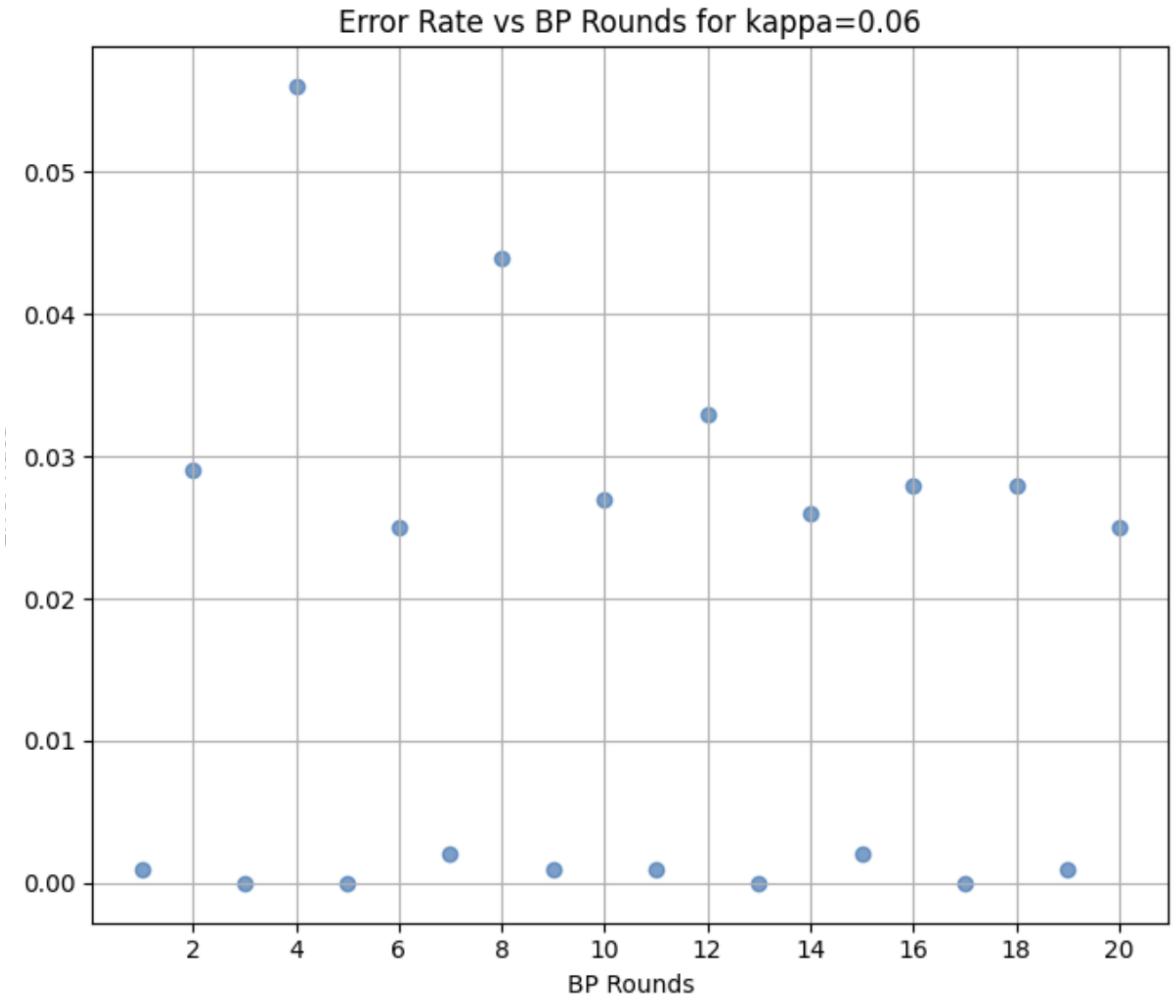



Figure: Error rates on one of our decoding problems.
They have mod 4 behaviour.

# Possible improvements

- randomisation of update order
- random drop out
- momentum/damping (like in Machine Learning)
- postprocessing steps
- ...