COMP3411 Week 02 Tutorial

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https://github.com/hharryyf/COMP3411-24T1-tutoring

Q1

Solve the following Cryptarithmetic puzzle. State the heuristics and strategies used. The same character represents the same digit and different characters represent different dights.

$$\begin{array}{r} \text{SEND} \\ +\text{MORE} \\ \hline \text{MONEY} \end{array}$$

Q1

Recall CSP variable/value selection heuristics

- Minimum Remaining Values
  - Choose the variable with the fewest legal values
- Degree heuristics (Tie-break MRV)
  - Choose the variable with the most constraints on the remaining variables.
- Least Constraining Value
  - Value selection heuristic: choose the value that rules out the fewest values in the remaining variables

Q1

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- M = 1 (Minimum Remaining Values)

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$$\begin{array}{r} \text{SEND} \\ +\text{1ORE} \\ \hline \text{1ONEY} \end{array}$$

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- O = 0 or 1 (Minimum Remaining Values)

Q1

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- M = 1 (Minimum Remaining Values)

$$\begin{array}{r} \text{SEND} \\ +\text{1ORE} \\ \hline \text{1ONEY} \end{array}$$

- O = 0 or 1 (Minimum Remaining Values)
- O = 0, since M != O

Q1

$$\begin{array}{r} \text{SEND} \\ +\text{10RE} \\ \hline \text{10NEY} \end{array}$$

Q1

$$\begin{array}{r} \text{SEND} \\ +\text{10RE} \\ \hline \text{10NEY} \end{array}$$

- S = 8 or 9 (Minimum Remaining Values)

Q1

$$\begin{array}{r} \text{SEND} \\ +\text{10RE} \\ \hline \text{10NEY} \end{array}$$

- S = 8 or 9 (Minimum Remaining Values)
  - If S = 8

$$\begin{array}{r} \text{8}\color{red}{9}\text{ND} \\ +\text{10R}\color{red}{9} \\ \hline \text{10N}\color{red}{9}\text{Y} \end{array}$$

Q1

$$\begin{array}{r} \text{SEND} \\ +\,10\text{RE} \\ \hline 10\text{NEY} \end{array}$$

- S = 8 or 9 (Minimum Remaining Values)
  - If S = 8

$$\begin{array}{r} 8\color{red}{9}\text{ND} \\ +\,10\text{R}\color{red}{9} \\ \hline 10\text{N}\color{red}{9}\text{Y} \end{array}$$

  - N = 0, conflict!

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- S = 8 or 9 (Minimum Remaining Values)
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  - N = 0, conflict!
- S = 9

Q1

$$\begin{array}{r} 9\text{END} \\ +10\text{RE} \\ \hline 10\text{NEY} \end{array}$$

- E + 1 = N

Q1

$$\begin{array}{r} 9END \\ +10RE \\ \hline 10NEY \end{array}$$

- E + 1 = N
  - N + R = 10 + E or N + R + 1 = 10 + E

Q1

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- E + 1 = N
  - N + R = 10 + E or N + R + 1 = 10 + E
  - If N + R = 10 + E, R = 9, conflict!

Q1

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- E + 1 = N
  - N + R = 10 + E or N + R + 1 = 10 + E
  - If N + R = 10 + E, R = 9, conflict!
  - N + R + 1 = 10 + E is the only possibility, R = 8

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$$\begin{array}{r} 9END \\ +108E \\ \hline 10NEY \end{array}$$

Q1

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  - If N + R = 10 + E, R = 9, conflict!
  - N + R + 1 = 10 + E is the only possibility, R = 8

$$\begin{array}{r} 9END \\ +108E \\ \hline 10NEY \end{array}$$

- D + E = 10 + Y, E + 1 = N

Q1

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  - N + R = 10 + E or N + R + 1 = 10 + E
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- D + E = 10 + Y, E + 1 = N
- remaining values 2, 3, 5, 6, 7

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  - If Y = 3, E = 6 or 7

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- D + E = 10 + Y, E + 1 = N
- remaining values 2, 3, 5, 6, 7
- Y = 2 or 3 (Minimum Remaining Values)
  - If Y = 3, E = 6 or 7
    - E = 6 means N = 7 and D = 7, conflict

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- Y = 2 or 3 (Minimum Remaining Values)
  - If Y = 3, E = 6 or 7
    - E = 6 means N = 7 and D = 7, conflict
    - E = 7 means N = 8, conflict
  - Y = 2, and E = 5 or 7

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- remaining values 2, 3, 5, 6, 7
- Y = 2 or 3 (Minimum Remaining Values)
  - If Y = 3, E = 6 or 7
    - E = 6 means N = 7 and D = 7, conflict
    - E = 7 means N = 8, conflict
  - Y = 2, and E = 5 or 7
  - E = 5 and D = 7 and N = 6 is the only solution

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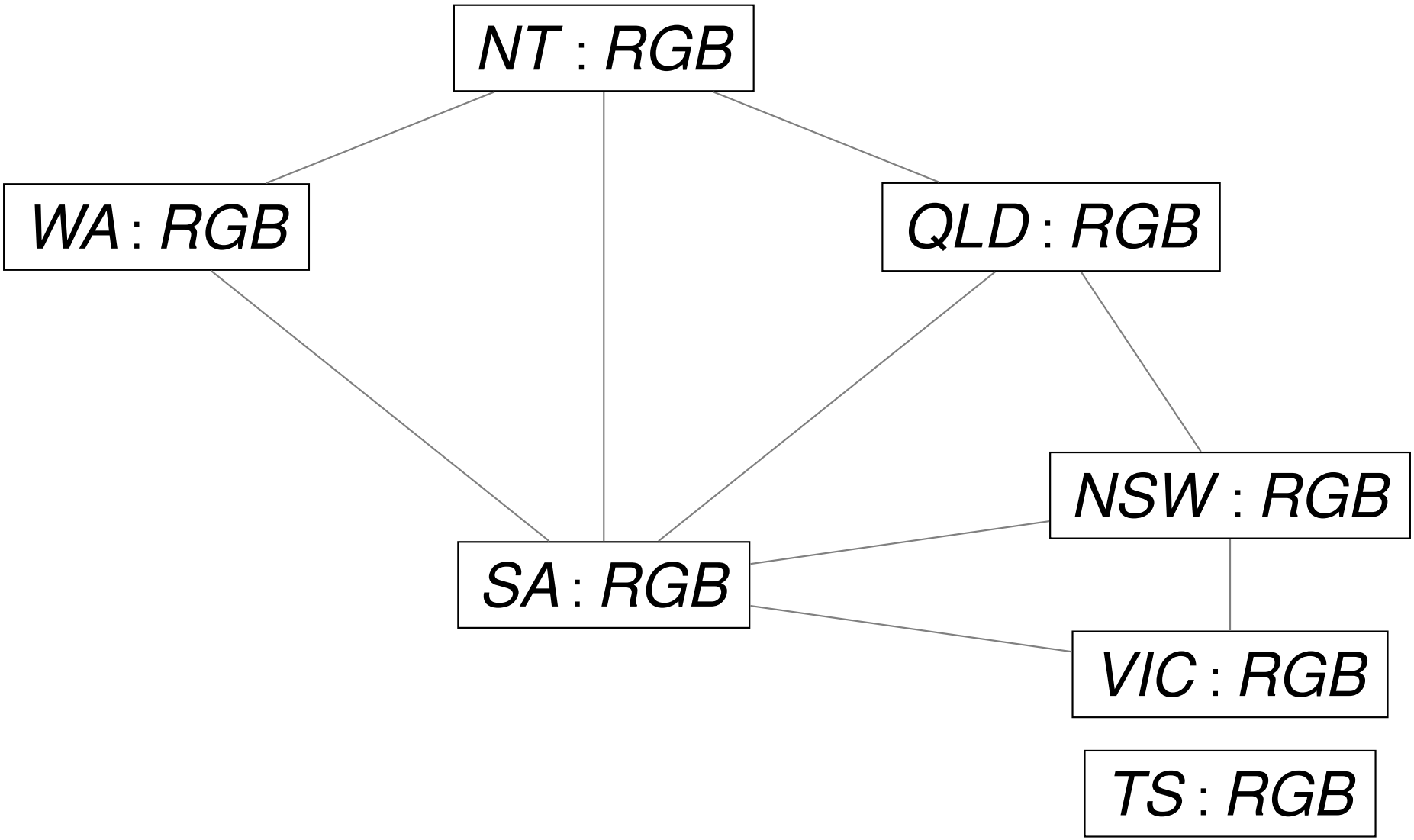
- D + E = 10 + Y, E + 1 = N
- remaining values 2, 3, 5, 6, 7
- Y = 2 or 3 (Minimum Remaining Values)
  - If Y = 3, E = 6 or 7
    - E = 6 means N = 7 and D = 7, conflict
    - E = 7 means N = 8, conflict
  - Y = 2, and E = 5 or 7
  - E = 5 and D = 7 and N = 6 is the only solution

$$\begin{array}{r} 9567 \\ +1085 \\ \hline 10652 \end{array}$$

Q2

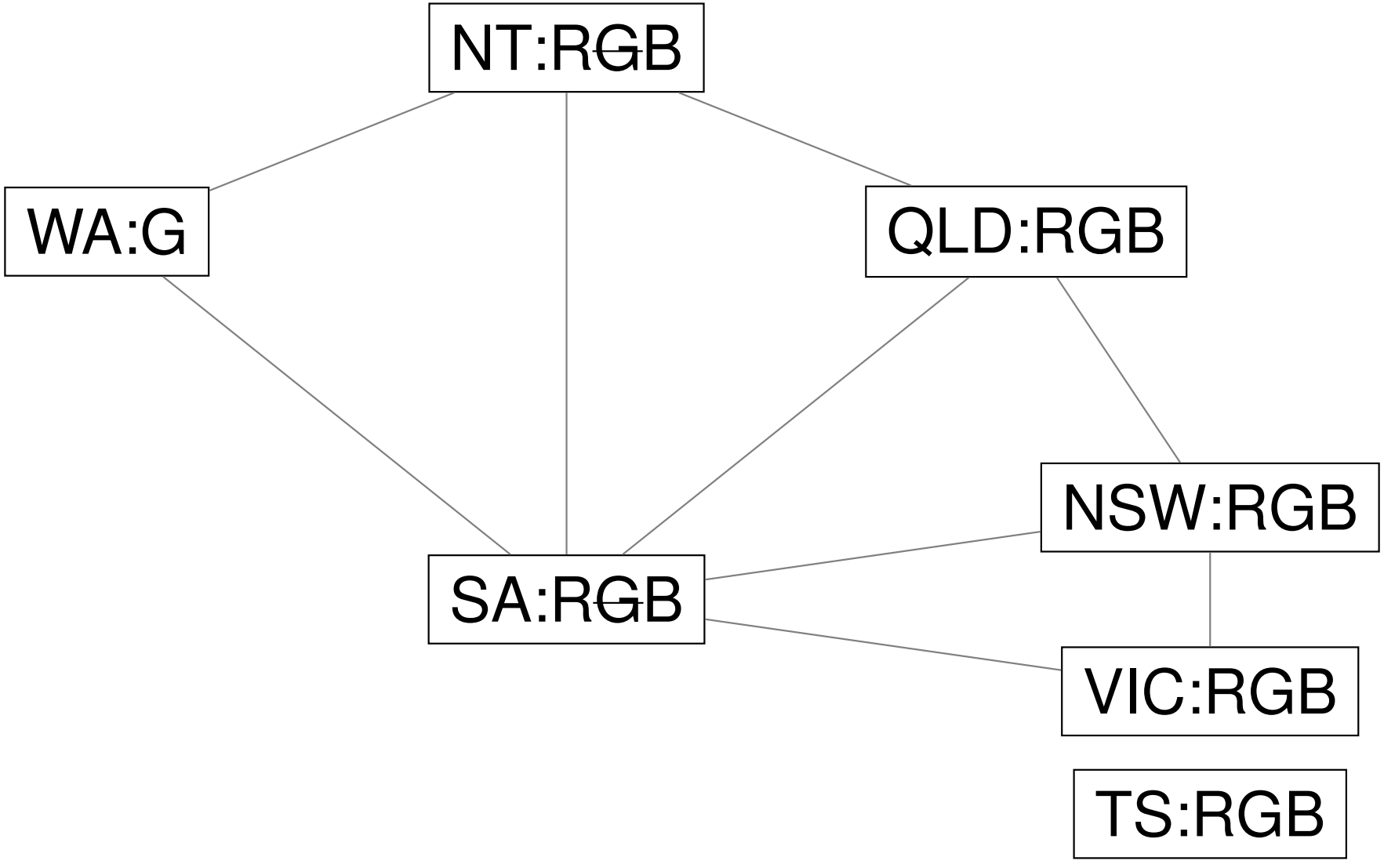
- Forward Checking (FC)
- Maintain Arc consistency (MAC)

Q2



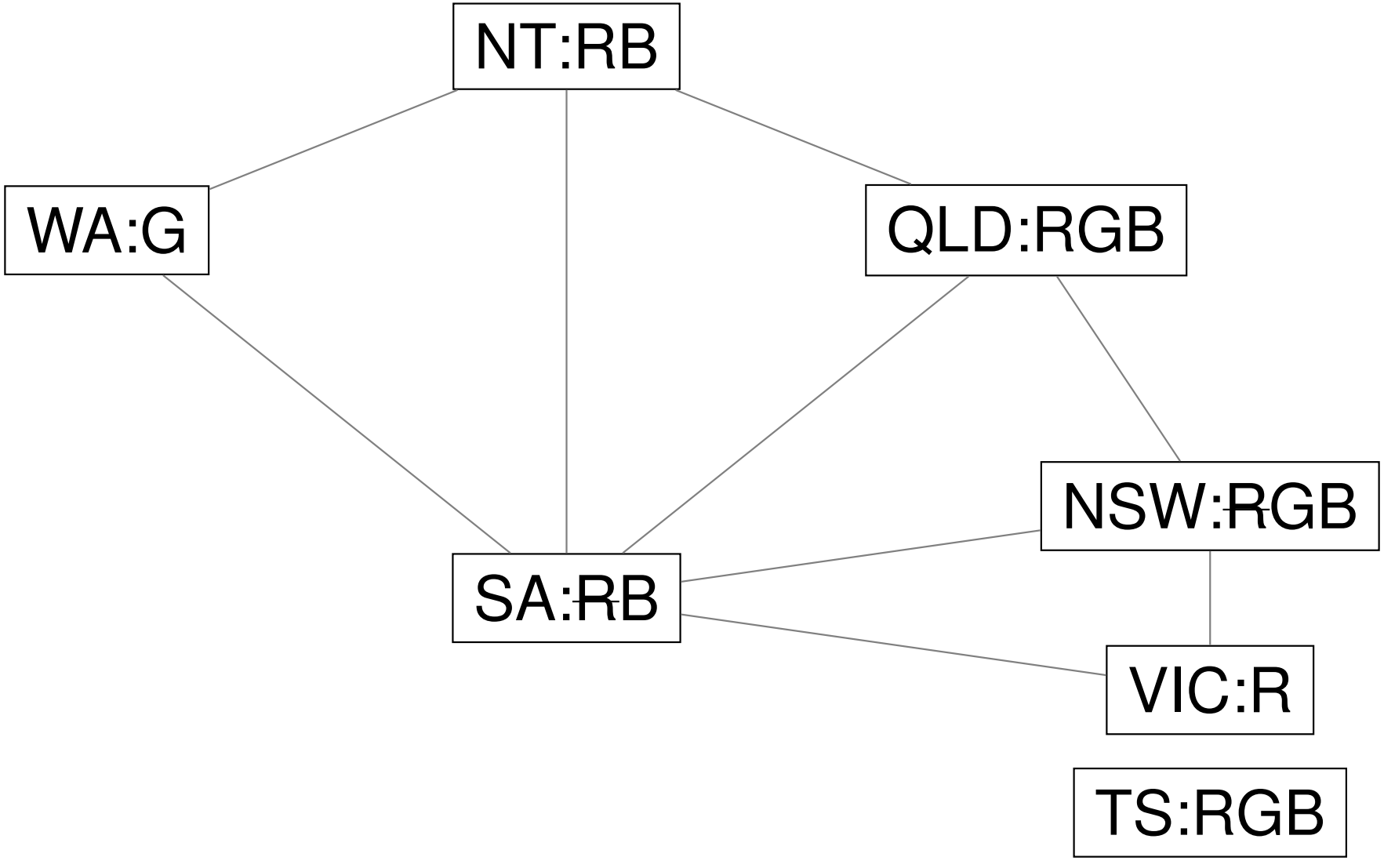
Q2: FC only

- Assign WA: G



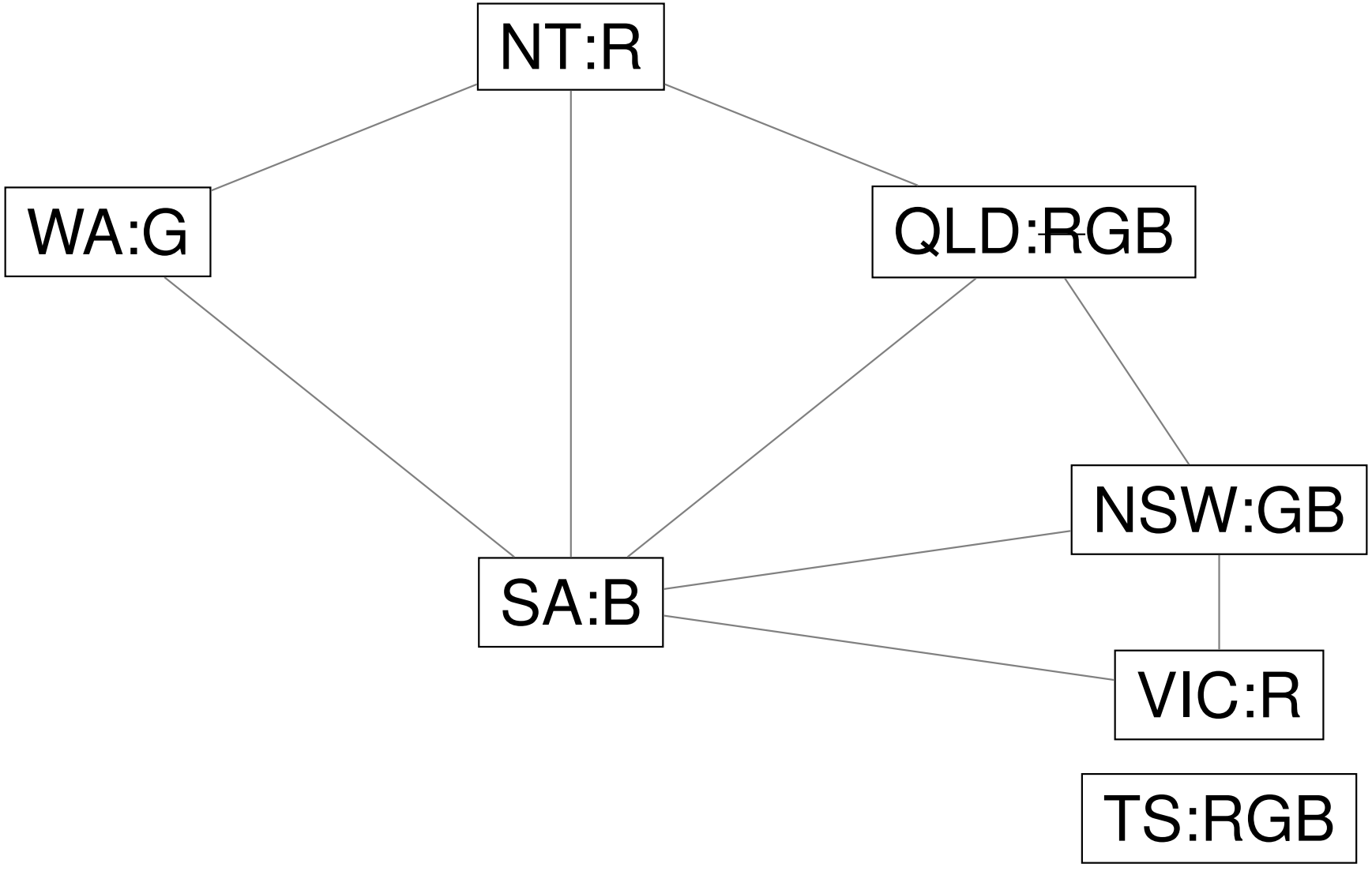
Q2: FC only

- Assign WA: G, VIC: R



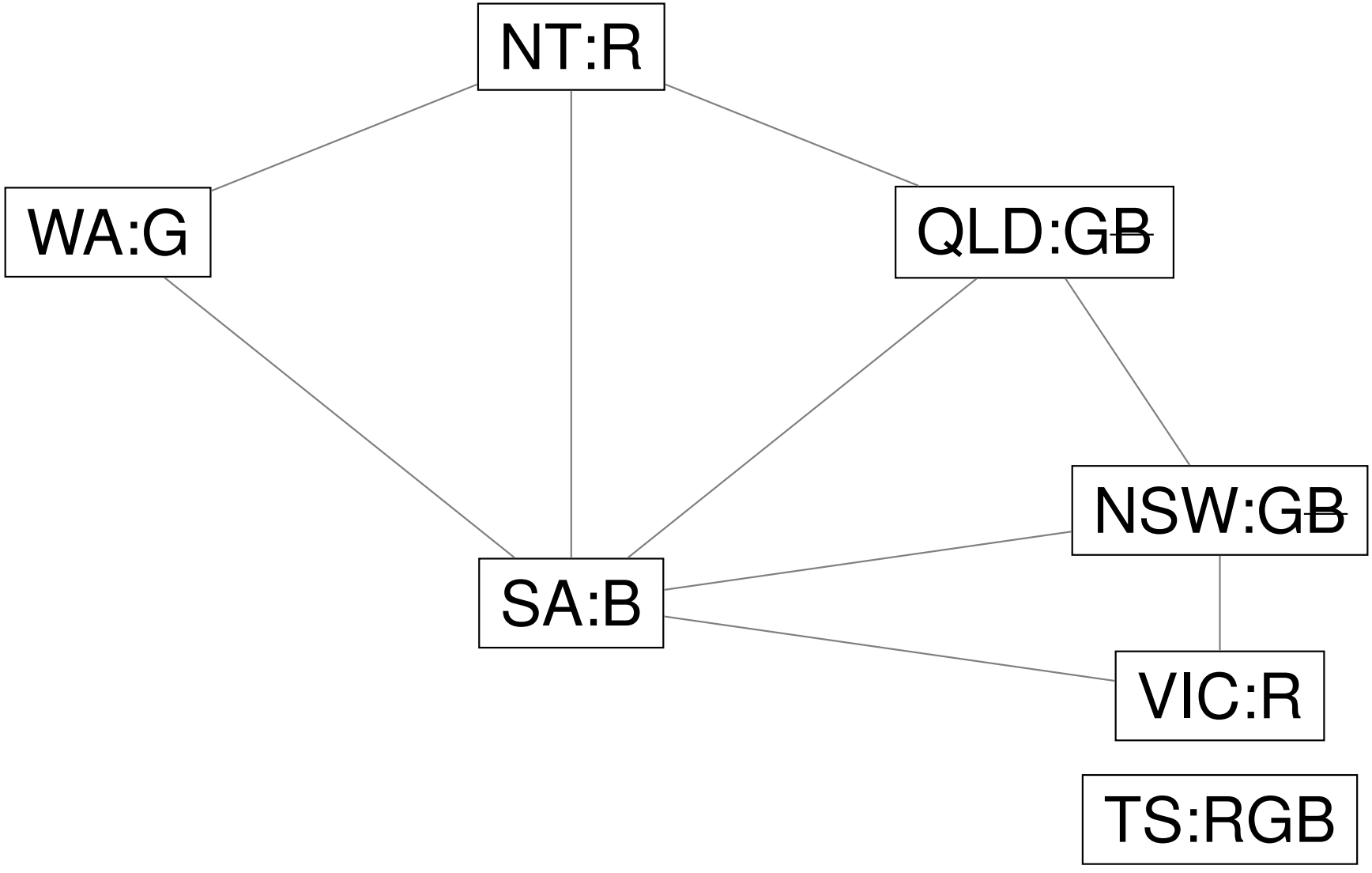
Q2: FC only

- Assign WA: G, VIC: R, NT: R



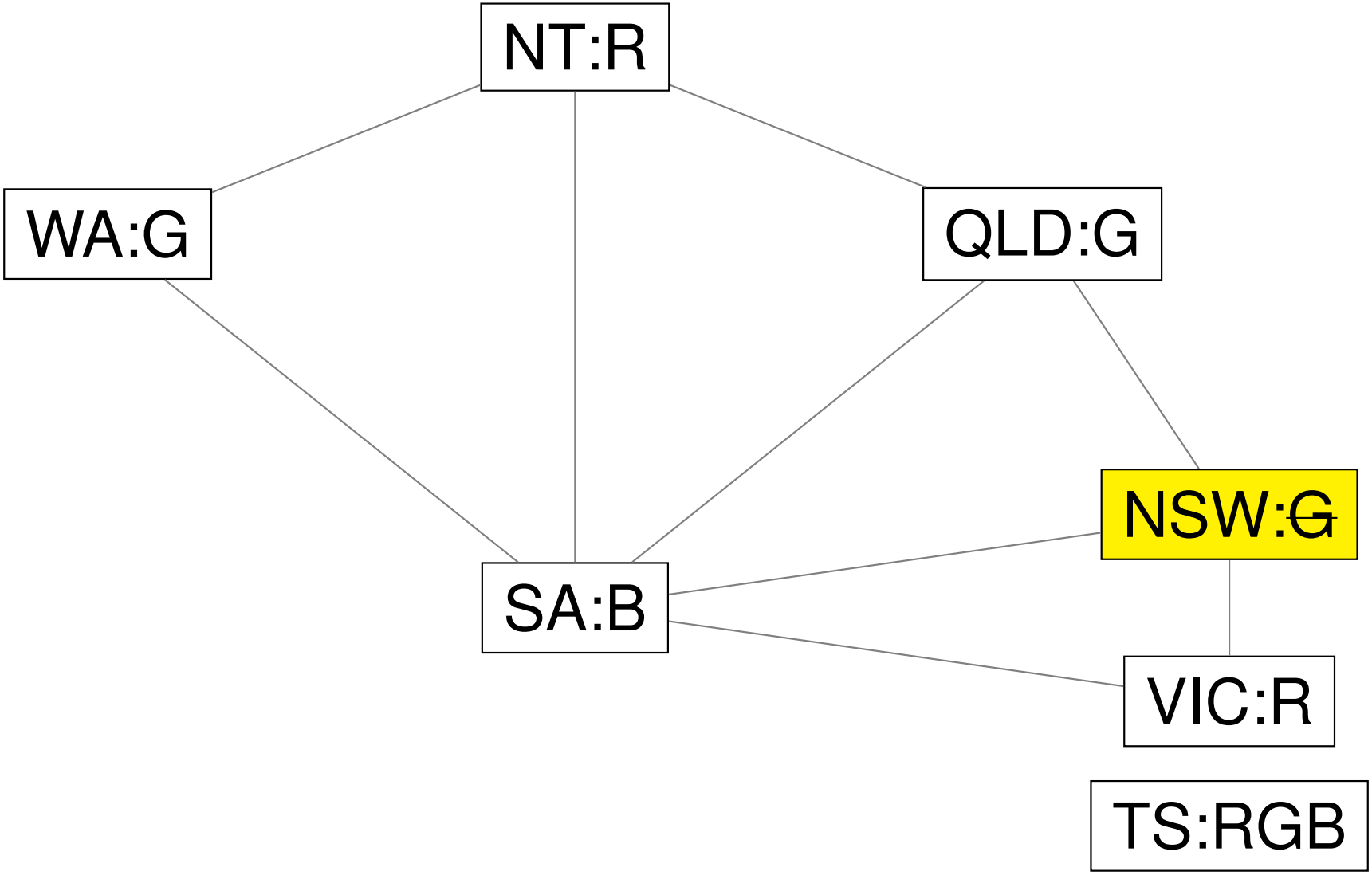
Q2: FC only

- Assign WA: G, VIC: R, NT: R, SA can only be B

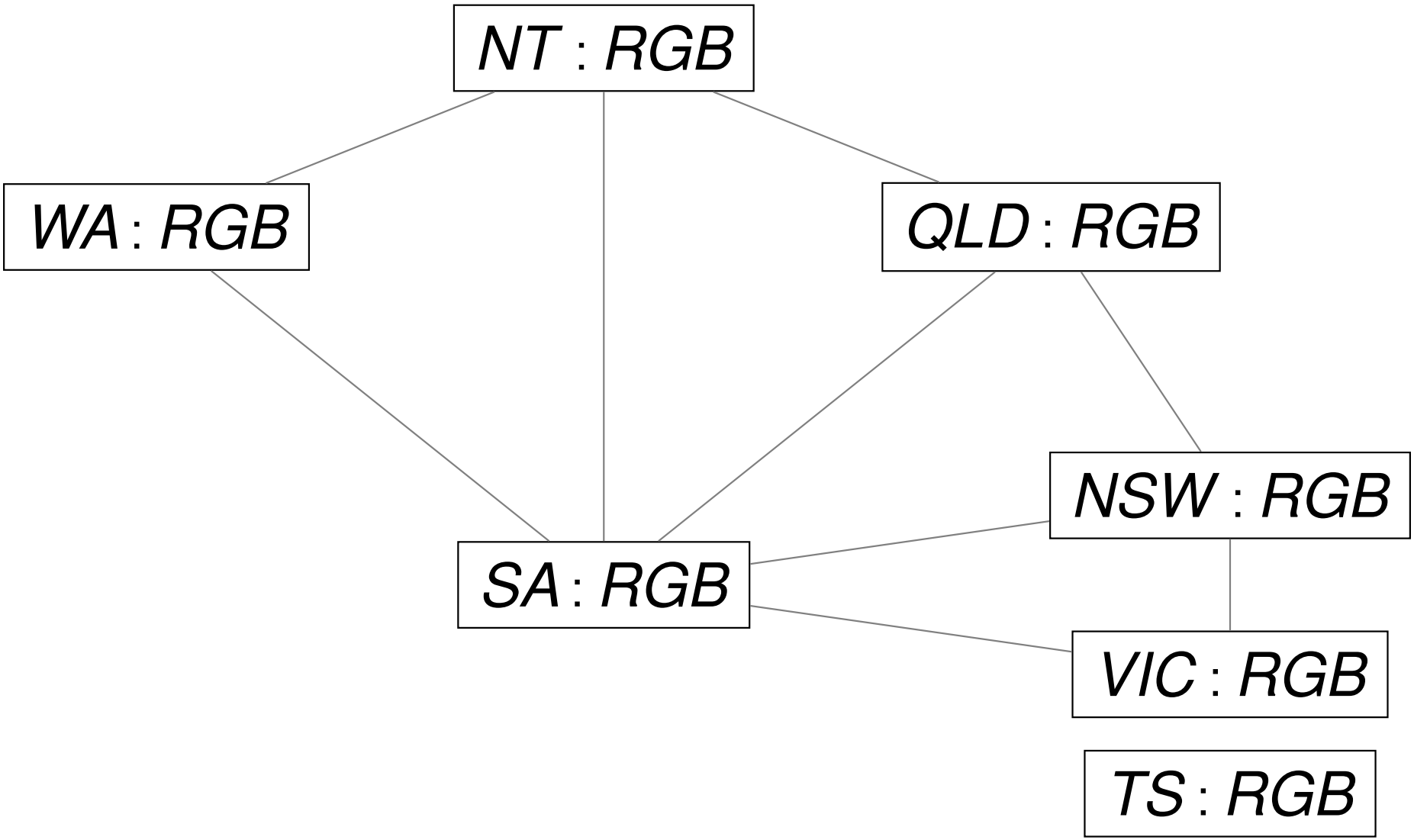


Q2: FC only

- Assign WA: G, VIC: R, NT: R, SA: B, QLD: G

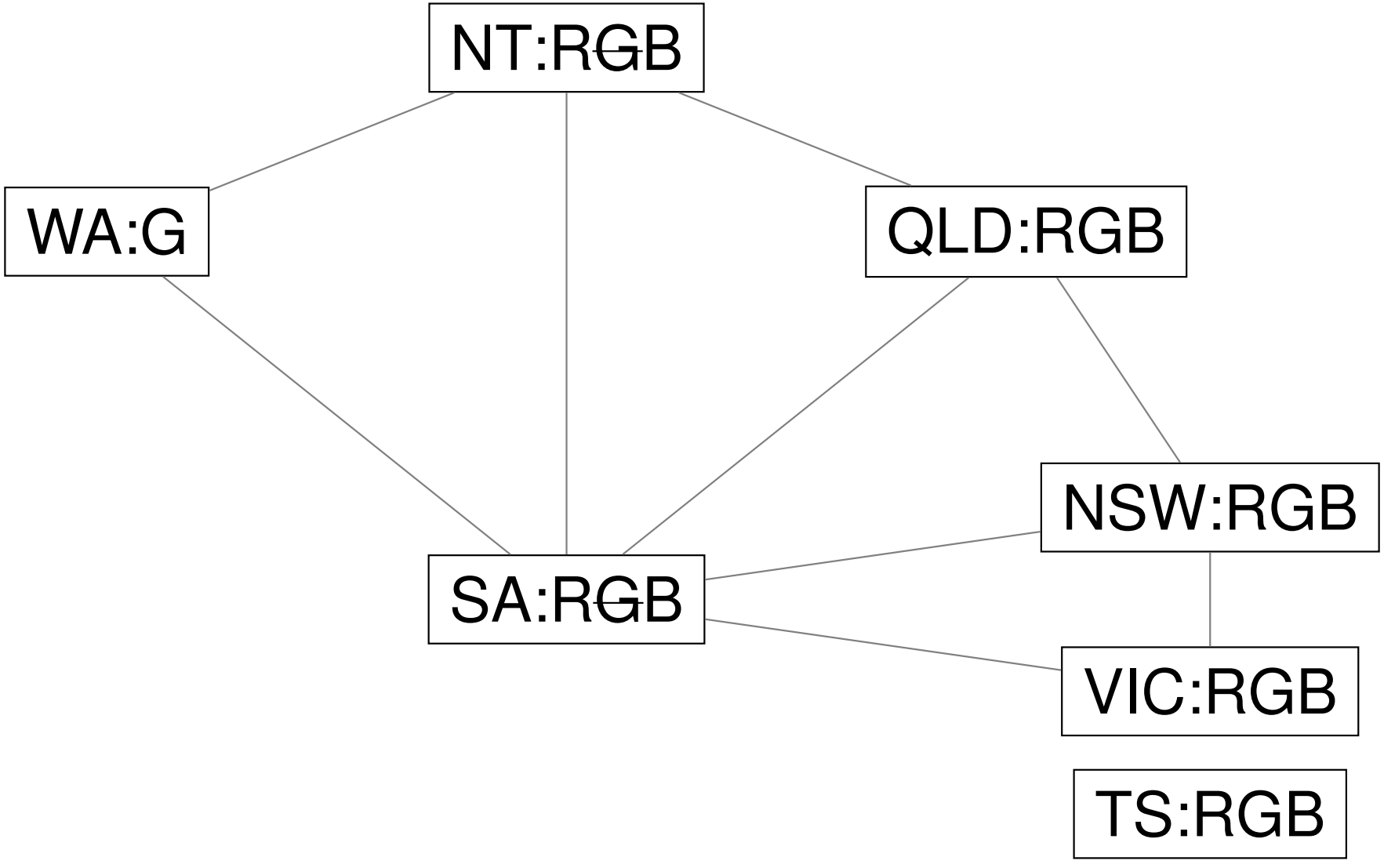


Q2



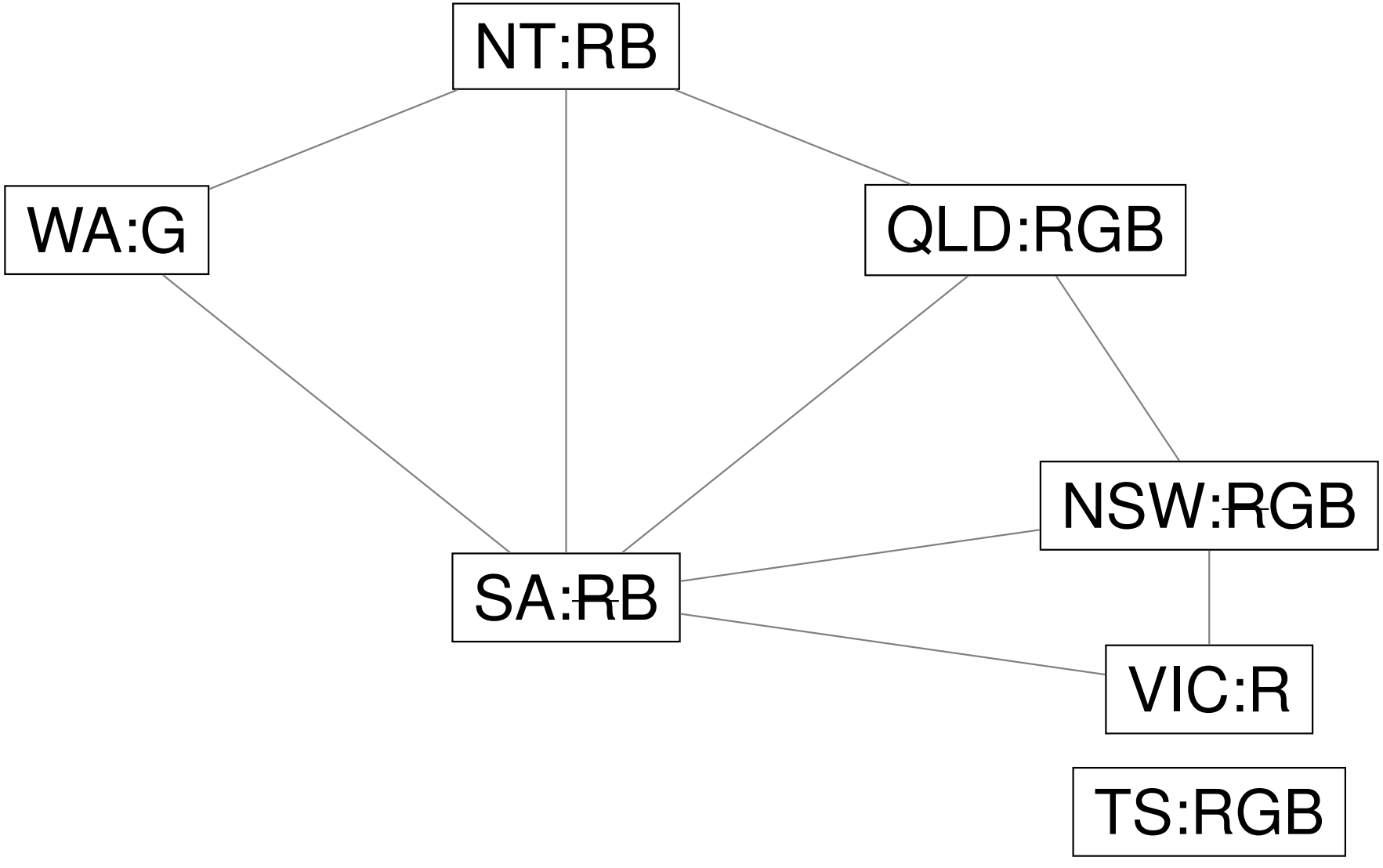
Q2: FC + MAC

- Assign WA: G



Q2: FC + MAC

- Assign WA: G, VIC: R



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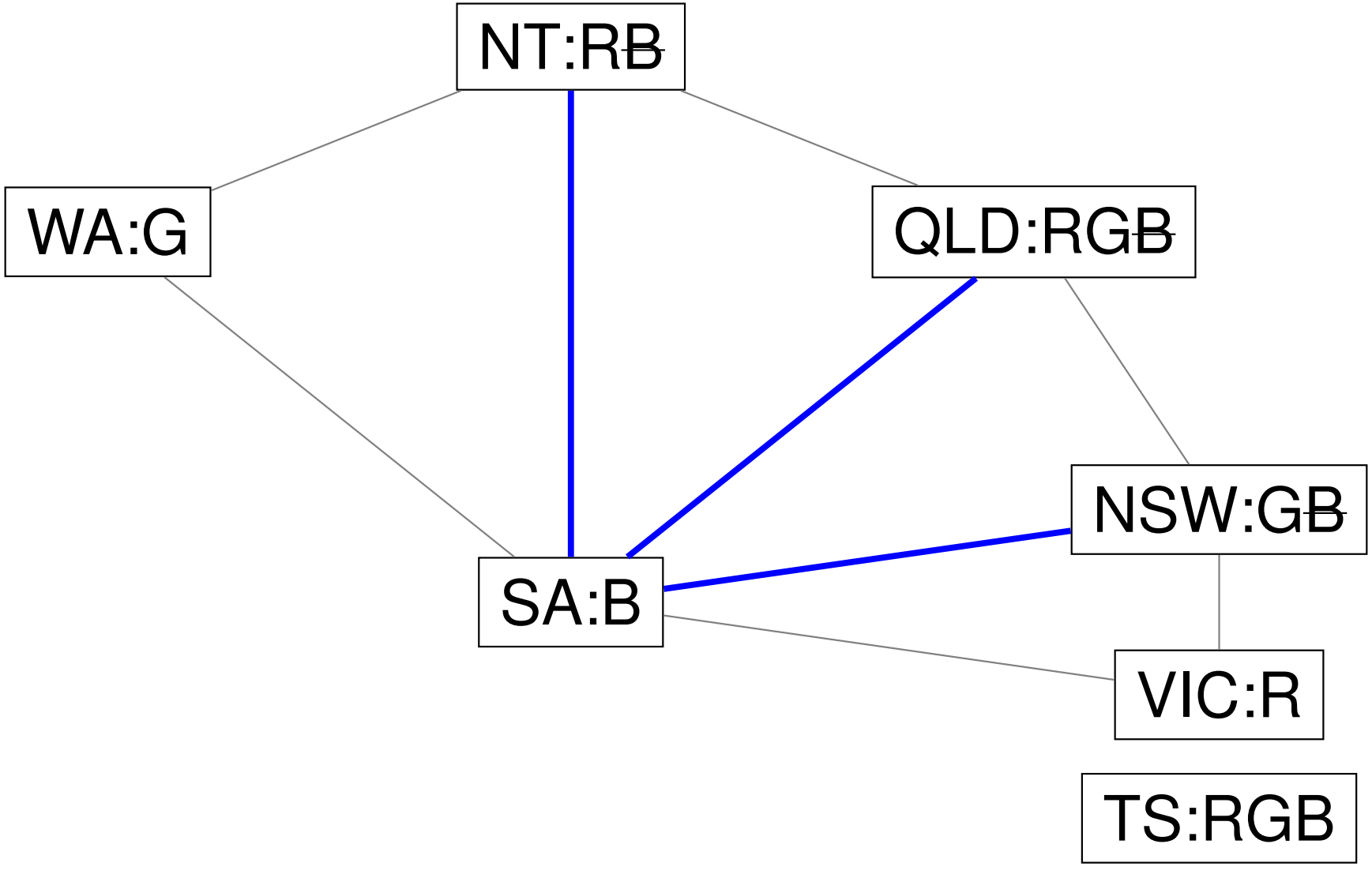

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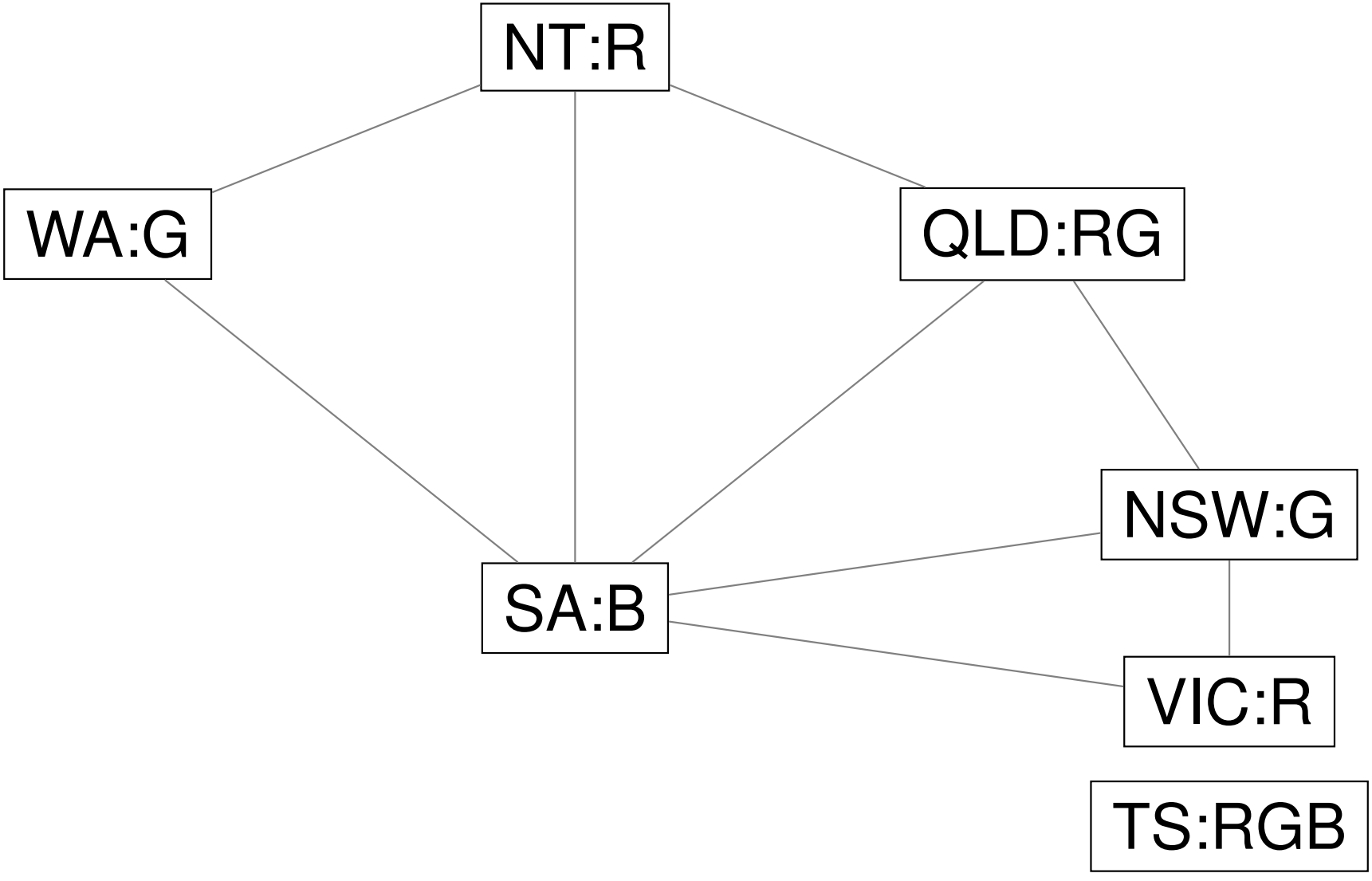

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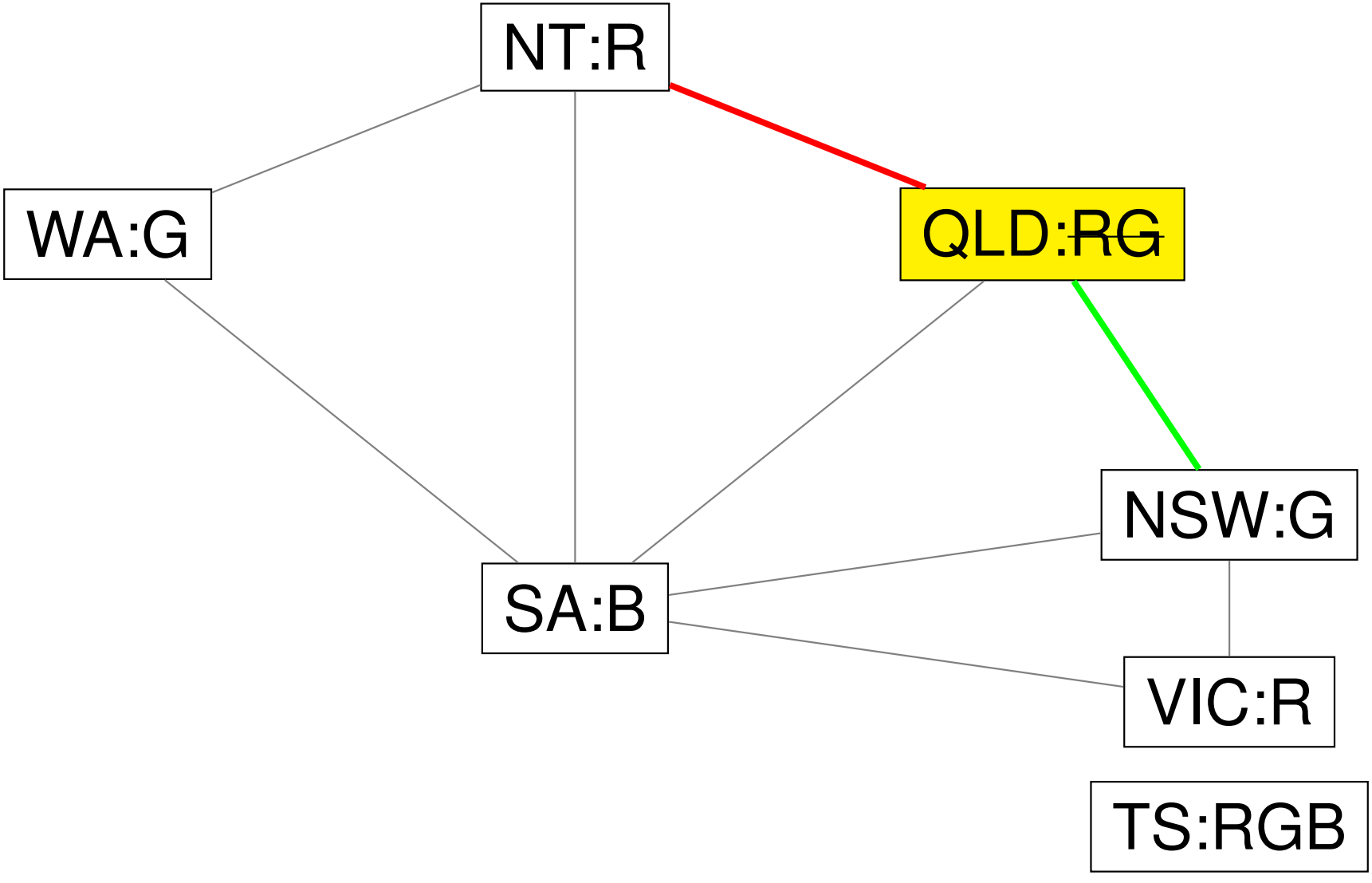
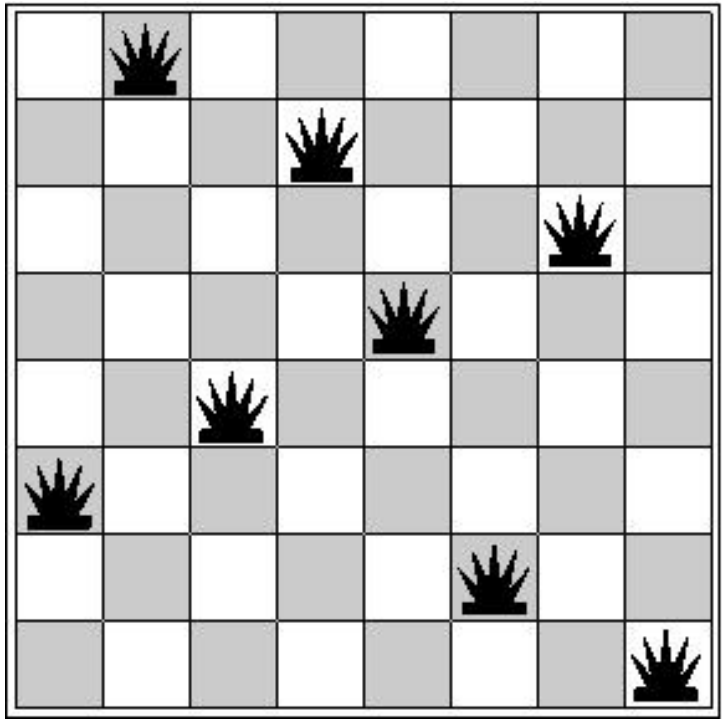
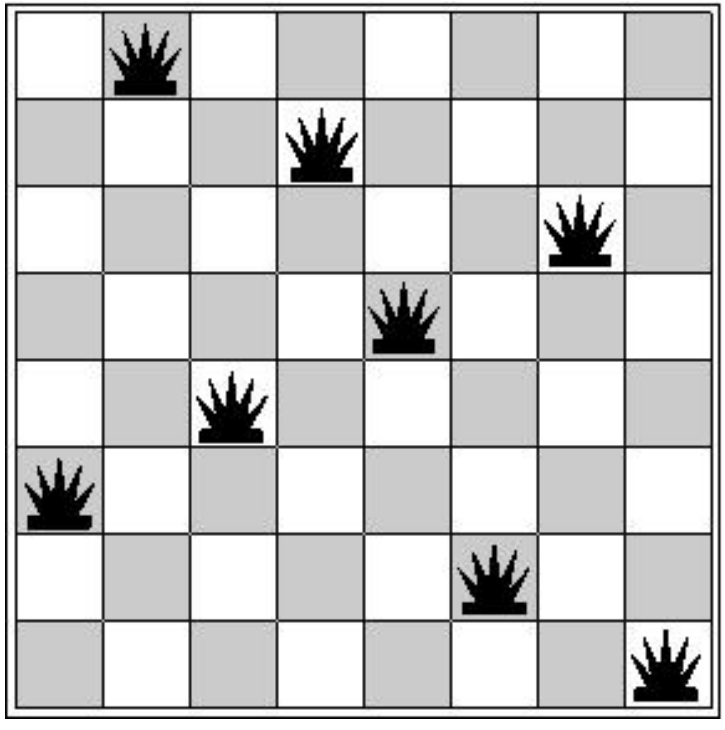


Q3

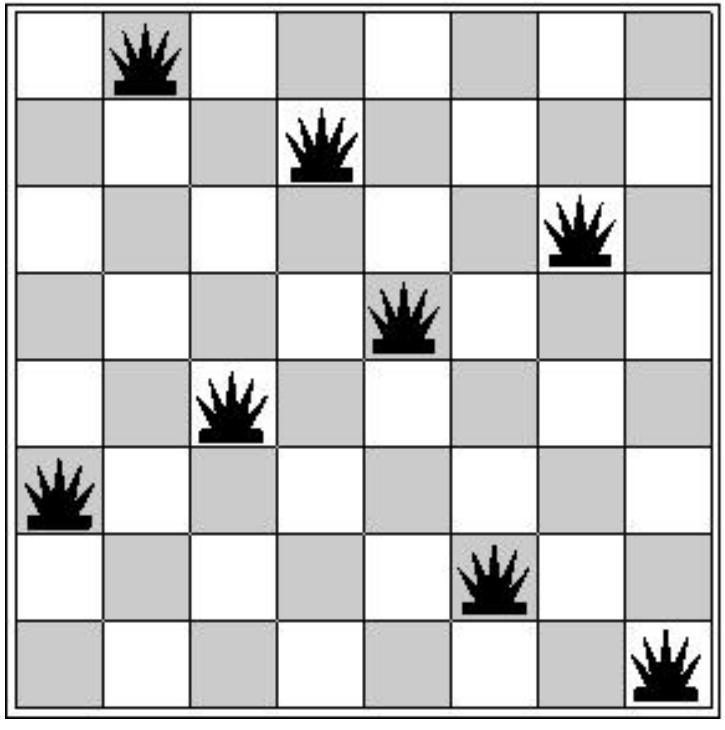


Q3



- The queens in columns 2 and 5 are attacking each other (h = 1)

Q3



- The queens in columns 2 and 5 are attacking each other (h = 1)
- Easy to verify that it is impossible to reduce h by hill-climbing alone

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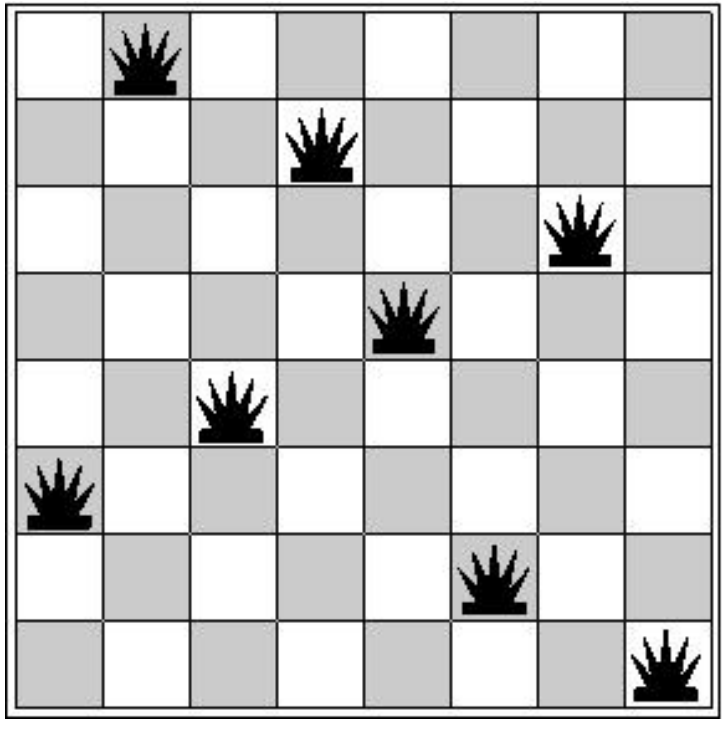

- The queens in columns 2 and 5 are attacking each other (h = 1)
- Easy to verify that it is impossible to reduce h by hill-climbing alone
  - We need to move either the queen in column 2 or 5, but that would create at least a "row" conflict.

Q3

- Why Simulated Annealing may Succeed eventually

Q3

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- Recall that SA is a local search algorithm
  1. Start from a random **x** configuration
  2. Draw a random configuration in the neighborhood
  3. If the new configuration **x'** is better, let $x = x'$
  4. Otherwise, draw a random number $p \in [0,1]$, let $x = x'$ with probability p, return to step 1.
- p is drawn from a probability distribution similar to the Boltzmann distribution in Physics

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  1. Start from a random **x** configuration
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  3. If the new configuration **x'** is better, let $x = x'$
  4. Otherwise, draw a random number $p \in [0, 1]$, let $x = x'$ with probability p, return to step 1.
- p is drawn from a probability distribution similar to the Boltzmann distribution in Physics
- Step 1-3 of the algorithm is just hill-climbing, step 4 might help us to escape the local minimum

Q3

- If you want to read more about local search, the paper "General local search methods" is highly recommended [1]
- It contains 3 very popular local search methods:
  - Simulated Annealing
  - Tabu Search
  - Genetic Algorithm

[1] https://www.sciencedirect.com/science/article/pii/0377221796000070

Q4

- We'll skip the problem, you can solve it in your free time
- If you know Prolog or ASP, it is a good exercise