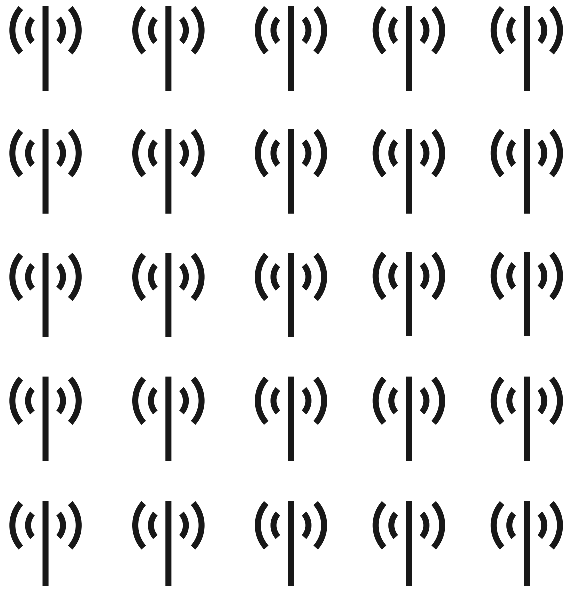
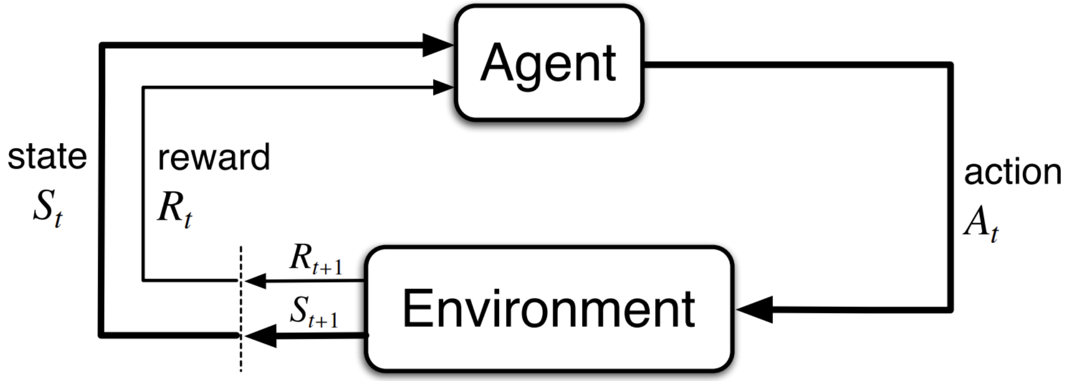
Network Scenario

- Inspired by Ozturk et al. (2021) in the BS activation problem for energy saving.
- Consider a simple network topology of 25 Macro BSs in a 5x5 grid.
$$\mathcal{B} = \{B_1, B_2, B_3, B_4, \ldots, B_{25}\}$$
- Assume that all BSs in the grid have coverage overlaps
- Assume a centralized controller can monitor and manage the entire network topology

➔ Objective: MDP for turning on/off BSs. If a BS is turning OFF, its load is share to neighbor BSs. Controller perform action on BS sequentially (BSs perform action one by one)





State space

- State space will contain 2 traffic matri
  - **Traffic demand (D):** The original tr
    - $0 \leq d_j^t \leq 1$
    - Initiate all $d_j^0 = l_j^0 = 0.1$

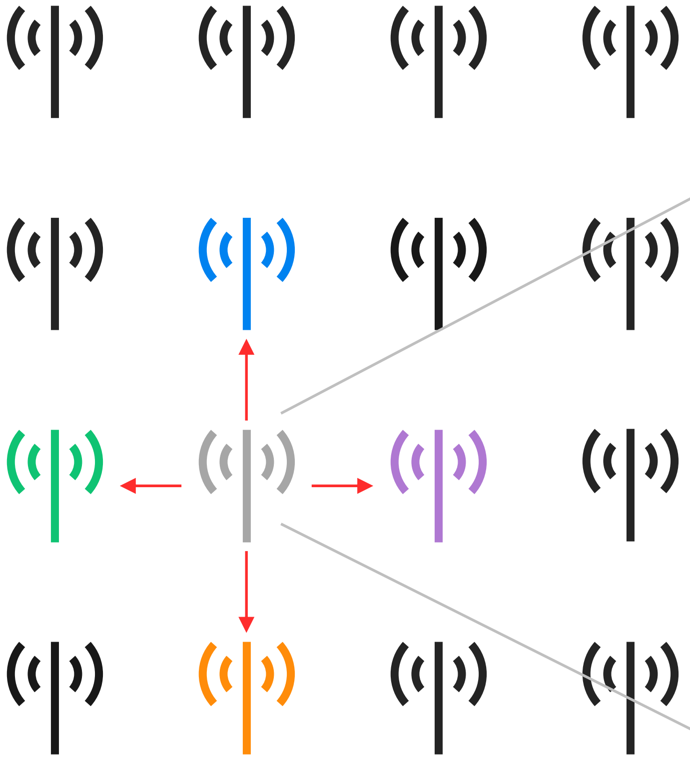
$$D^t = \begin{pmatrix} d_1^t & d_2^t & d_3^t & d_4^t & d_5^t \\ d_6^t & d_7^t & d_8^t & d_9^t & d_{10}^t \\ d_{11}^t & d_{12}^t & d_{13}^t & d_{14}^t & d_{15}^t \\ d_{16}^t & d_{17}^t & d_{18}^t & d_{19}^t & d_{20}^t \\ d_{21}^t & d_{22}^t & d_{23}^t & d_{24}^t & d_{25}^t \end{pmatrix}$$

Applying actions

  - **Traffic state (L):** The traffic load mat from time to time (from t=0 to t)
    - $l_j^t = 0$ indicates BS j is OFF
    - $0 \leq l_j^t \leq 1$
    - l_j^t is λ_j^t for calculating Power

$$L^t = \begin{pmatrix} l_1^t & l_2^t & l_3^t & l_4^t & l_5^t \\ l_6^t & l_7^t & l_8^t & l_9^t & l_{10}^t \\ l_{11}^t & l_{12}^t & l_{13}^t & l_{14}^t & l_{15}^t \\ l_{16}^t & l_{17}^t & l_{18}^t & l_{19}^t & l_{20}^t \\ l_{21}^t & l_{22}^t & l_{23}^t & l_{24}^t & l_{25}^t \end{pmatrix}$$

Action space



	0	Turning ON
0001	1	
…		
0110	6	
…		Turning OFF and shift load
1110	14	
…		
1111	15	
	16	Do nothing

Action space masking

- **<u>Action mask</u>**: Valid actions to perform at every step t
- The purpose of action masking is to ensure:
  - Do not perform action on the same previous BS (Avoid BS ON-OFF continuously)
  - Allow only feasible actions in each state
    - Do not share load to OFF BS
    - Do not turn off an already deactivated BS
    - BSs at edge may have less than 4 neighbors

Reward function

- Energy Consumption
  - Derived from the *Energy Aware Radio and neTwork tecHnologies* (EARTH) power consumption model

$$P_j = \begin{cases} P_{\mathrm{o},j} + \eta_j \lambda_j P_{\mathrm{T},j} & 0 < \lambda_j < 1, \\ P_{\mathrm{s},j} & \lambda_j = 0 \end{cases}$$

  - With $P_o = 130W, \eta = 4.7, P_T = 20W; P_S = 75W$ for Macro BS
- Traffic Loss
  - The maximum load of each BS is 1 ➔ Migrate load to a busy BS will lead to sacrifice of traffic loads (BSs load clip at 1)

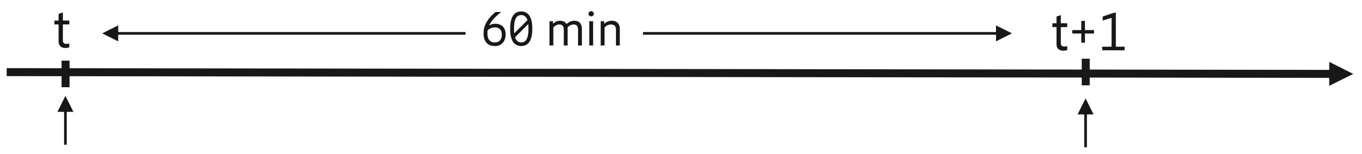
loss = sum($\boldsymbol{D^t}$) – sum($\boldsymbol{L^t}$)

- Reward function

$$\boxed{\boldsymbol{r^t = \sum_j (P^j_{max} - P^j_t) - 100 \times loss}}$$

Environment configuration

- State transitions:



$$s^t = (D^t, L^t) \quad \rightarrow \quad a^t \quad \rightarrow \quad s^{t+1},\ R^t = f(s^{t+1})$$

- Each episode contains: 24 (time intervals per day) * 1 (days per week) = <u>**24 steps**</u>
- Performance metrics (to be collect from _get_info):
  - Traffic coverage (%):

    traffic_coverage = sum(L^t)/sum(D^t) * 100

  - Energy saving (%):

    energy_saving = (total_P_all_ON – total_P)/ total_P_all_ON * 100