MPDL Base Station Sleep Control Algorithm and Variables

Algorithm 1: MPDL Base Station Sleep Control

Inputs:

- Initial network state: $X(0) = \{x_1(0), x_2(0), \ldots, x_N(0)\}$ (loads of all base stations).
- Arrival probabilities: v_i for each base station i.
- Departure probabilities: w_i for each base station i.
- Light sleep threshold L.
- Deep sleep decision function $J(u_i, u_j)$.

Steps:

1. **Initialization:**
   - Set the initial state $t = 1$ and $X(0)$.
2. **For each time step $t = 1$ to T:**
   - Randomly generate a parameter c between 0 and 1.
3. **Determine User Activity Based on c:**
   - If $\sum_{k=1}^{i-1} v_k < c \leq \sum_{k=1}^{i} v_k$ (A user arrives at base station i):
     - Case 1: If $u_i(t-1) = 0$ (base station is empty):
       * Find $\max J(1, u_j(t-1))$, where $j \in K(i)$ (neighboring base stations).
       * If $\max J(1, u_j(t-1)) > 0$:
         · Increment $u_j(t+1) = u_j(t) + 1$ (neighbor takes the user).
       * Else:
         · Set $u_i(t) = 1$ (base station becomes active).
     - Case 2: If $u_i(t-1) + 1 > U_{\max}$ (load exceeds capacity):
       * Find neighboring base stations $\{j | u_j(t-1) = 0\}$.
       * Distribute load among base station i and its neighbors:

$$u_i(t) = u_j(t) = \frac{u_i(t-1) + 1}{k+1}, \quad \text{where } k \text{ is the number of neighbors.}$$

     - Case 3: If $u_i(t-1) + 1 \leq U_{\max}$:
       * Increment $u_i(t) = u_i(t-1) + 1$.
   - If $\sum_{k=1}^{n} v_k + \sum_{k=1}^{i-1} w_k < c \leq \sum_{k=1}^{n} v_k + \sum_{k=1}^{i} w_k$ (A user departs from base station i):
     - Case 1: If the base station transitions to deep sleep:
       * Find $\max J(u_i(t-1) - 1, u_j(t-1))$, where $j \in K(i)$.
       * Distribute load among neighbors or wake up base station j.
   - If no user activity: (User remains stationary)
     - Retain the same state $X(t+1) = X(t)$.
4. **Evaluate Sleep Transitions:**

- If $\rho_i(t) < L$ (light sleep threshold) and delay $D(\rho_i)$ is acceptable:
  - Transition base station i to light sleep.
- If $\max J(u_i, u_j) > 0$ and neighbors can take the load:
  - Transition base station i to deep sleep.

5. **Update Network State:**
   - Adjust states $X(t + 1)$ based on user activity and base station transitions.

Variables and Formulas

Variable	Description	How to Find It
$X(t)$	Network state at time t, represented as $\{x_1(t), x_2(t), ..., x_N(t)\}$, where $x_i(t)$ is the load of base station i.	Update using user arrival (v_i) and departure (w_i).
v_i	Probability of a user arriving at base station i.	Typically modeled using a Poisson process.
w_i	Probability of a user leaving base station i.	Derived from user behavior or historical data.
$J(u_i, u_j)$	Decision function for deep sleep transition.	$J(u_i, u_j) = P(u_i) + P(u_j) - P(u_i + u_j) - w_{i,j}(u_i)$, where $P(u)$ is power consumption.
ρ_i	Load of base station i, defined as $\rho_i = \frac{u_i}{U_{\max}}$.	Calculate using u_i, the number of users, and $U_{\max}$, the base station's maximum capacity.
$P(u)$	Power consumption of the base station.	Different formulas for normal, light sleep, and deep sleep states: $$P(u) = \begin{cases} \frac{u}{U_{\max}} P_t + P_0 & \text{if active} \\ P_{\text{doze}} + F_m E_s & \text{if light sleep} \\ 0 & \text{if deep sleep} \end{cases}$$
F_m	Frequency of entering the doze state in light sleep.	$F_m = \frac{(U_{\max} - u)(1 - \Gamma_V)}{U_{\max} V}$.
Γ_V	Probability that there is no queue at the end of a doze window.	$\Gamma_V = e^{-p\mu V}$, where p is the probability of a request in a time slot, μ is service rate, and V is the doze window.
L	Light sleep threshold for base station i.	$L = -\frac{\ln\left(1 - \frac{V(P_0 - P_{\text{doze}})}{E_s}\right)}{Vp}$.
$w_{i,j}(u_i)$	Transition cost when moving users from base station i to j.	Typically a constant or function of user mobility.