Optimization Model (with steady-idle battery drain)

Constraints

$$
\begin{aligned}
&\text{(Max Battery Limit)} && b_n^k \le b_{\text{full}} && (1)\\
&\text{(Min Battery Limit)} && b_n^k \ge e_{\text{base}} && (2)\\
&\text{(Turn vs Move)} && y_{\text{turn},n}^k + y_{\text{mov},n}^k \le 1 && (3)\\
&\text{(Exchange vs No-Exchange)} && Y_{\text{exchange},n}^k + Y_{\text{noexchange},n}^k \le 1 && (4)\\
&\text{(Binary Turn Limit)} && y_{\text{turn},n}^k \in \{0,1\} && (5)\\
&\text{(Binary Move Limit)} && y_{\text{mov},n}^k \in \{0,1\} && (6)\\
&\text{(Binary Exchange Limit)} && Y_{\text{exchange},n}^k \in \{0,1\} && (7)\\
&\text{(Binary No-Exchange Limit)} && Y_{\text{noexchange},n}^k \in \{0,1\} && (8)\\
&\text{(Exchange implies station presence)} && Y_{\text{exchange},n}^k \le z_{\text{base\_station},n}^k && (9)\\
&\text{(Non-negativity steady drain)} && b_{\text{steady}} \ge 0 && (10)
\end{aligned}
$$

Battery update rule (including steady idle drain)

When the agent does *not* exchange ($Y_{\text{noexchange},n}^k = 1$) there are three mutually-exclusive energy-consumption cases in one step:

- turning: $y_{\text{turn},n}^k = 1 \to$ consume b_{turn},
- moving: $y_{\text{mov},n}^k = 1 \to$ consume b_{mov},
- idle: neither turning nor moving ($y_{\text{turn},n}^k = 0,\ y_{\text{mov},n}^k = 0$) $\to$ consume b_{steady}.

A compact linear expression that captures these cases is:

$$
\begin{aligned}
b_n^{k+1} = Y_{\text{noexchange},n}^k \cdot \Big(b_n^k - y_{\text{turn},n}^k \cdot b_{\text{turn}} - y_{\text{mov},n}^k \cdot b_{\text{mov}} \\
- \big(1 - y_{\text{turn},n}^k - y_{\text{mov},n}^k\big) \cdot b_{\text{steady}} \Big) \\
+ Y_{\text{exchange},n}^k \cdot b_{\text{full}}.
\end{aligned} \tag{11}
$$

(Explanation: when neither turn nor move occurs, the multiplier $(1 - y_{\text{turn}} - y_{\text{mov}})$ equals 1, so the idle drain b_{steady} is applied. If turning or moving happens, that term becomes zero.)

Objective Function (multi-objective, updated energy term)

$$
\max \quad \sum_{i=1}^{M} c_i \ . \tag{12}
$$

$$
\begin{aligned}
\min \quad & \sum_{n,k} \Big(y^k_{\text{turn},n} \cdot b_{\text{turn}} + y^k_{\text{mov},n} \cdot b_{\text{mov}} \\
& \qquad\qquad + \big(1 - y^k_{\text{turn},n} - y^k_{\text{mov},n}\big) \cdot b_{\text{steady}} \Big) \cdot Y^k_{\text{noexchange},n} \\
& \qquad\qquad\quad + \sum_{n,k} Y^k_{\text{exchange},n} \cdot \big(b_{\text{full}} - b^k_n\big).
\end{aligned} \tag{13}
$$