Formal Model: Inter-Domain AS-Level Carbon-Aware Routing
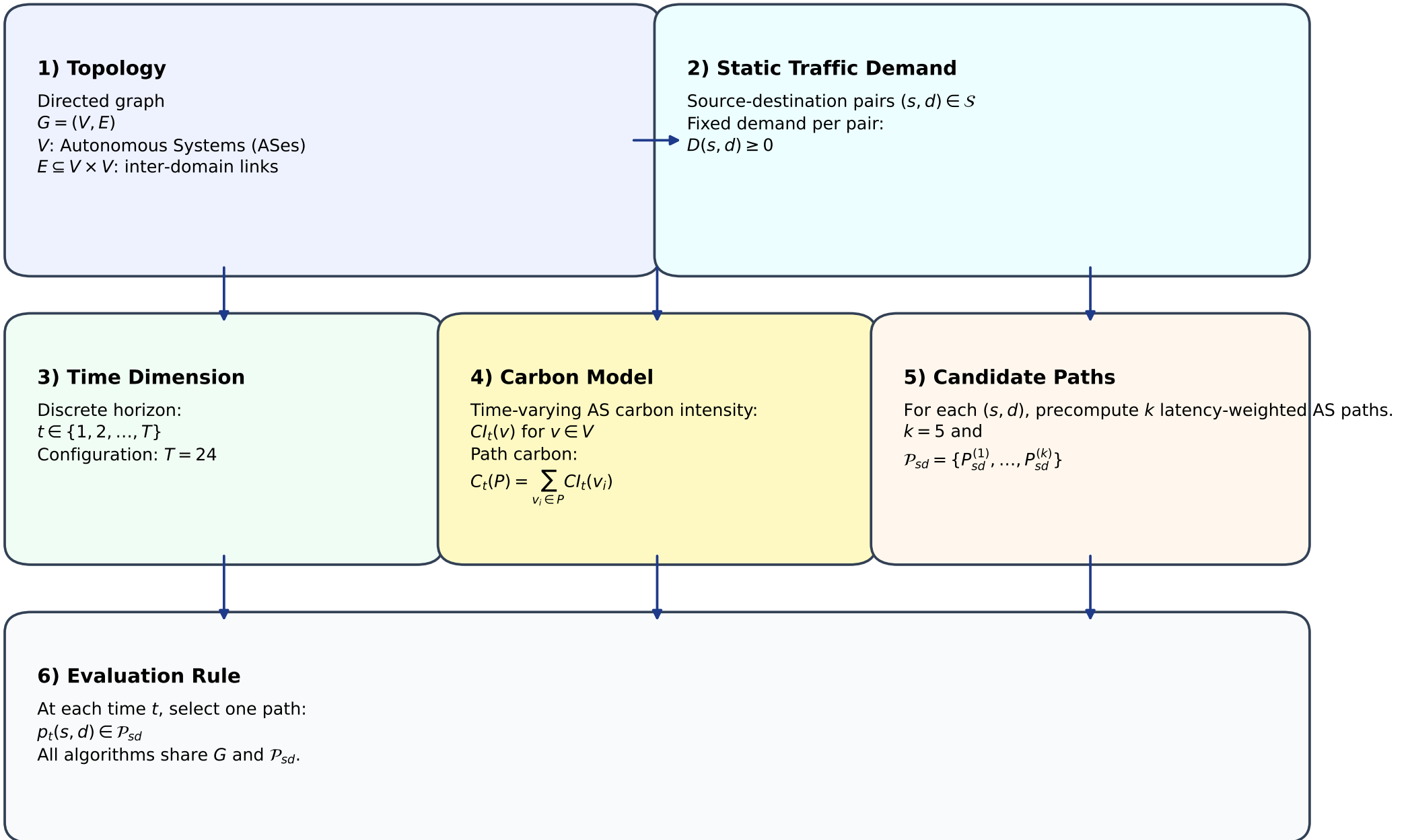
Thesis-ready abstraction with shared topology and comparable candidate paths.

1) Topology

Directed graph
$G = (V, E)$
V: Autonomous Systems (ASes)
$E \subseteq V \times V$: inter-domain links

2) Static Traffic Demand

Source-destination pairs $(s, d) \in \mathcal{S}$
Fixed demand per pair:
$D(s, d) \geq 0$

3) Time Dimension

Discrete horizon:
$t \in \{1, 2, ..., T\}$
Configuration: $T = 24$

4) Carbon Model

Time-varying AS carbon intensity:
$CI_t(v)$ for $v \in V$
Path carbon:
$$C_t(P) = \sum_{v_i \in P} CI_t(v_i)$$

5) Candidate Paths

For each (s, d), precompute k latency-weighted AS paths.
$k = 5$ and
$\mathcal{P}_{sd} = \{P_{sd}^{(1)}, ..., P_{sd}^{(k)}\}$

6) Evaluation Rule

At each time t, select one path:
$p_t(s, d) \in \mathcal{P}_{sd}$
All algorithms share G and $\mathcal{P}_{sd}$.

Conceptual Diagram: Data and Decision Flow

AS topology, static demand, dynamic carbon signal, and per-step path selection.

AS Graph $G = (V, E)$

Directed AS-level topology
used by all evaluated algorithms.

AS2 — AS4
AS1
AS6
AS3 — AS5

Static Traffic Demand

$D(s, d)$ for all $(s, d) \in \mathcal{S}$

Time-Varying Carbon

$CI_t(v)$ per AS and per time step

Time Index

$t \in \{1, \ldots, 24\}$

Candidate Path Generation

Precompute $k = 5$ latency-based
paths $\mathcal{P}_{sd}$ per (s, d)

Path Evaluation Block

For each t: evaluate path carbon

$$C_t(P) = \sum_{v_i \in P} CI_t(v_i)$$

and choose $p_t(s, d) \in \mathcal{P}_{sd}$