



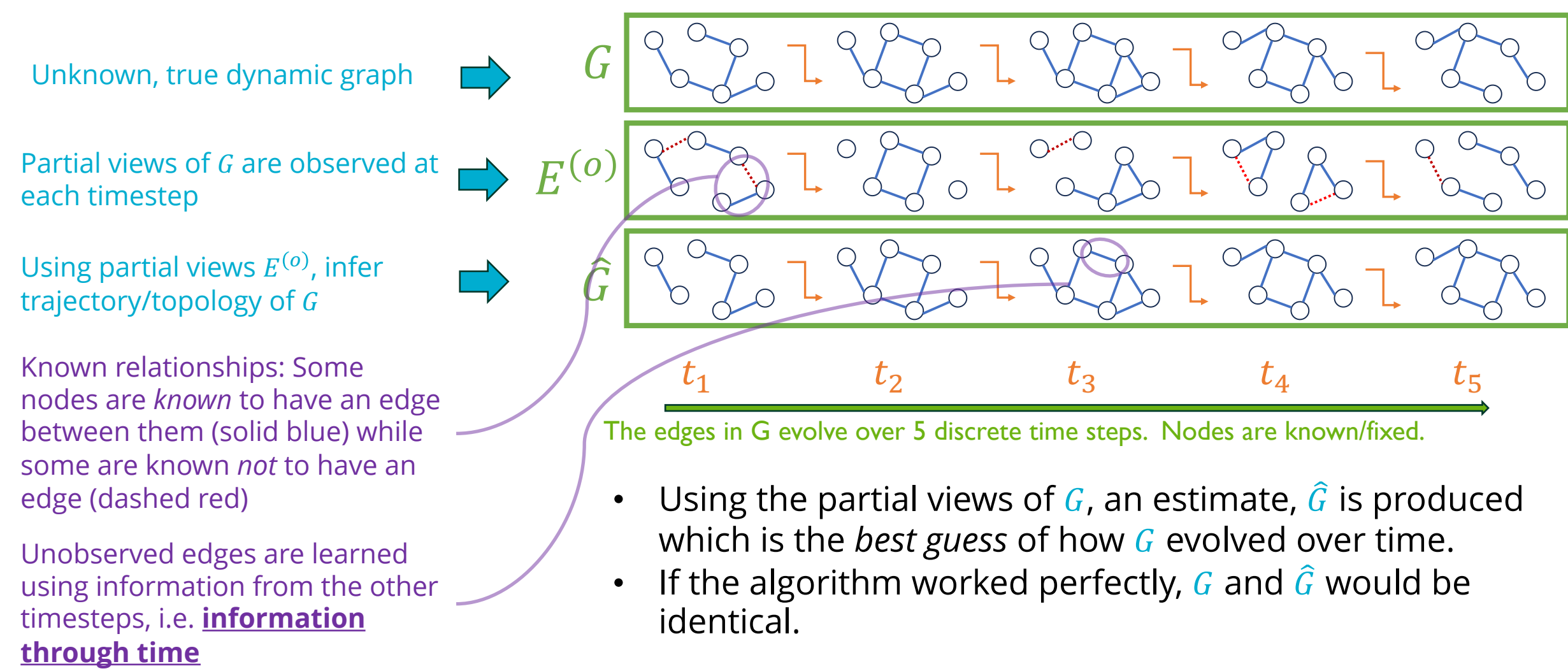
DynaHGraph: Learning Hidden Relationships in Dynamic Graphs

Kurtis Shuler and Lekha Patel

Project Goal:

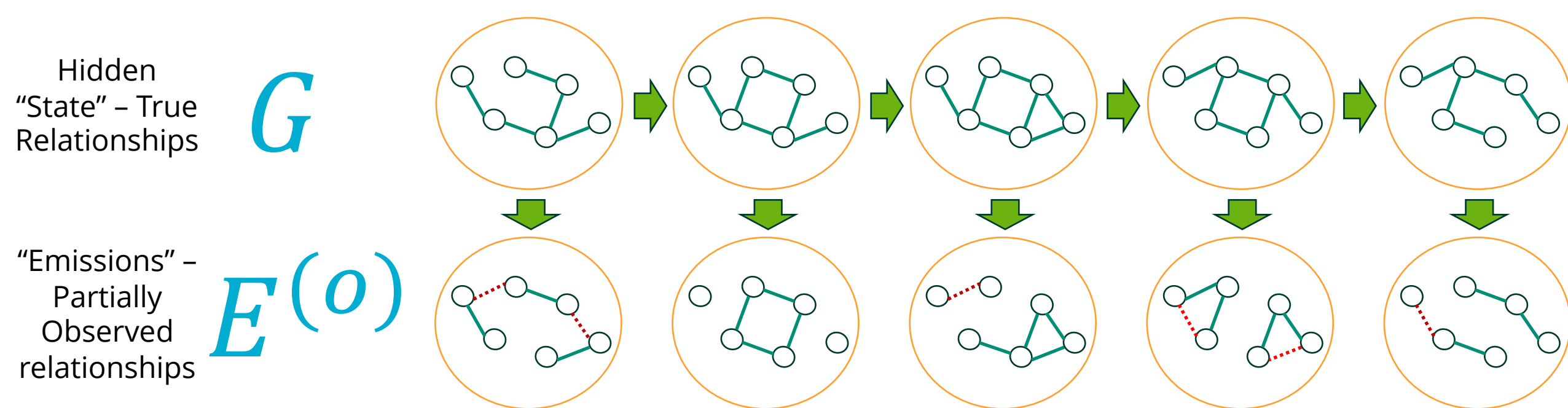
- Infer topology of a dynamic graph when network links are only partially known/observed

Estimate dynamic graph when it is only partially observed at each timestep



State-space Approach

- Use Hidden Markov Model representation to infer graph's topology over (discrete) time



Model

- Define a dynamic graph $G_t = [V, E_t]$ with fixed node-set $V = \{1, \dots, J\}$ and dynamic edge set E_t
- We consider a probability model where the graph's configuration at time t depends only on the previous time-step:

$$P(G_t | x_t, z_t, G_{t-1}, G_{t-2}, \dots) = P(G_t | x_t, z_t, G_{t-1}),$$

- And may depend on some global covariates x_t or node specific covariates $z_t = [z_{t1}, \dots, z_{tj}]$
- The observables' (emissions) probabilities $P(E^{(o)}_t | G_t)$ are defined conditionally on the graph's configuration at time t
- Use a dynamic programming approach (modified Viterbi algorithm) to produce best-guess estimates \hat{G} and uncertainty in the form of trajectory probabilities $P(G_1, \dots, G_T)$

Extensions, challenges, & Future Work

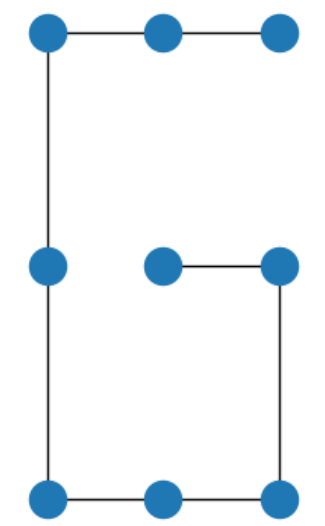
- Large state when number of nodes J is large creates challenges in scalability
- Deep graph NN and other latent/lower dimensional representations create opportunities for scaling to bigger graphs
- Treat edge formation as a stochastic (Hawkes) process to handle continuous time (on-going work)

Example

- Predict a graph's trajectory when the state space is letters coming from a 14 segment display (9 nodes):

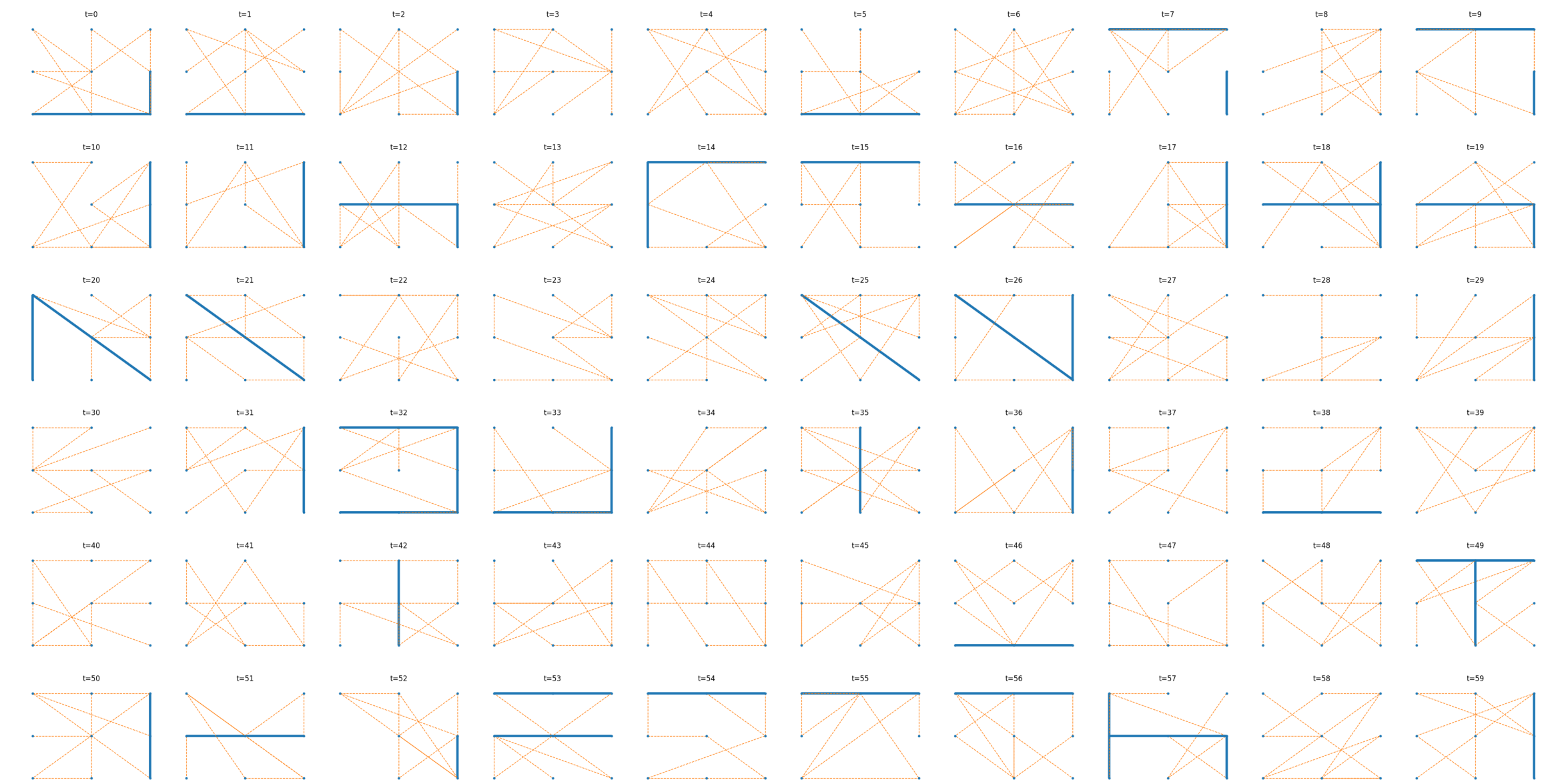


Letter "G":



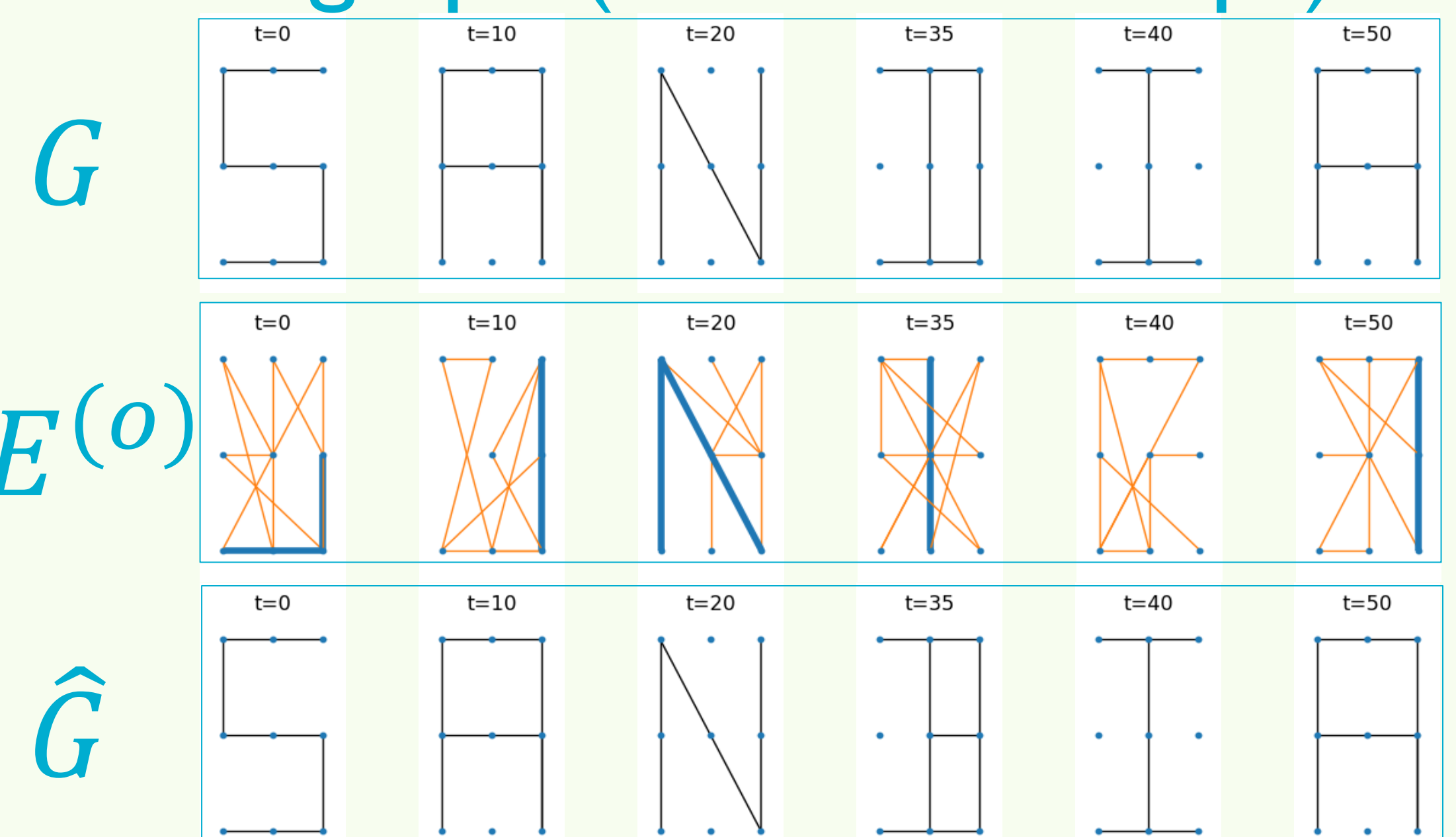
- Emissions consist of confirmed edges (blue) and confirmed edgeless (orange) node pairs in discrete time
- 10 node pairs chosen randomly at each time step for observation:

Emissions



- Estimated trajectory closely matches inferred trajectory, allowing the message (approximately) be decoded

Inferred graph (select timesteps):



Inferred graph (all timesteps):

