Dynamic Closed-loop Replanning in Belief Space: Toward Handling Dynamically Changing Environments

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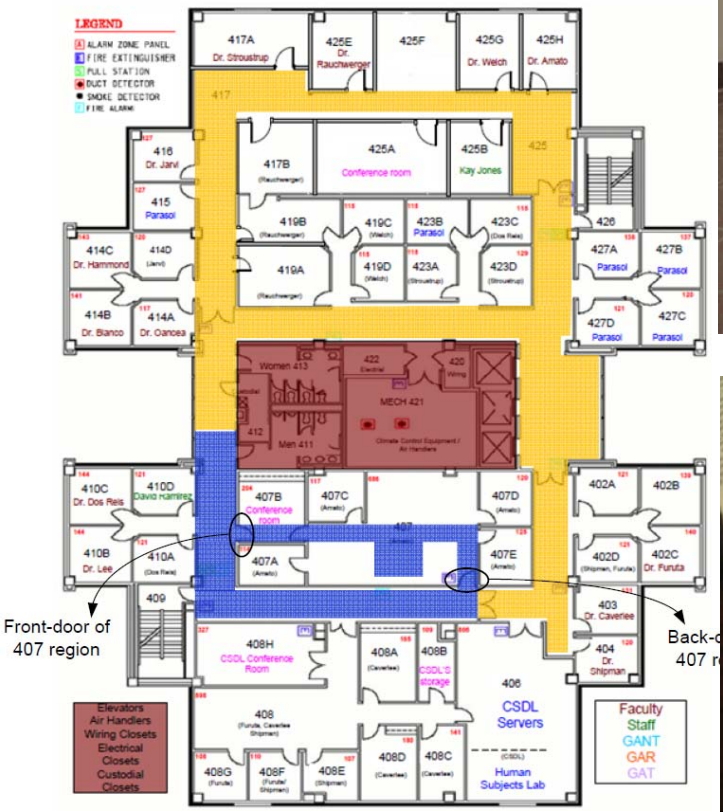
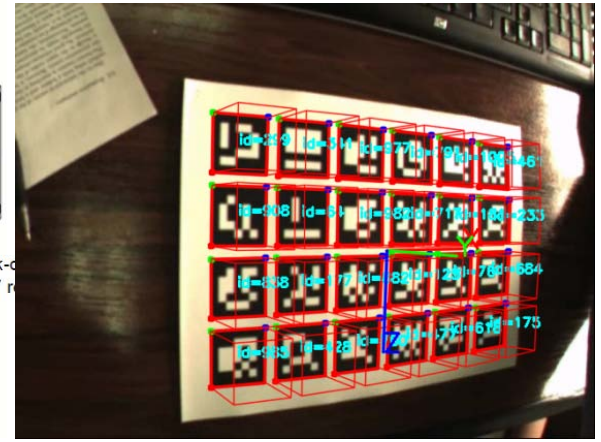
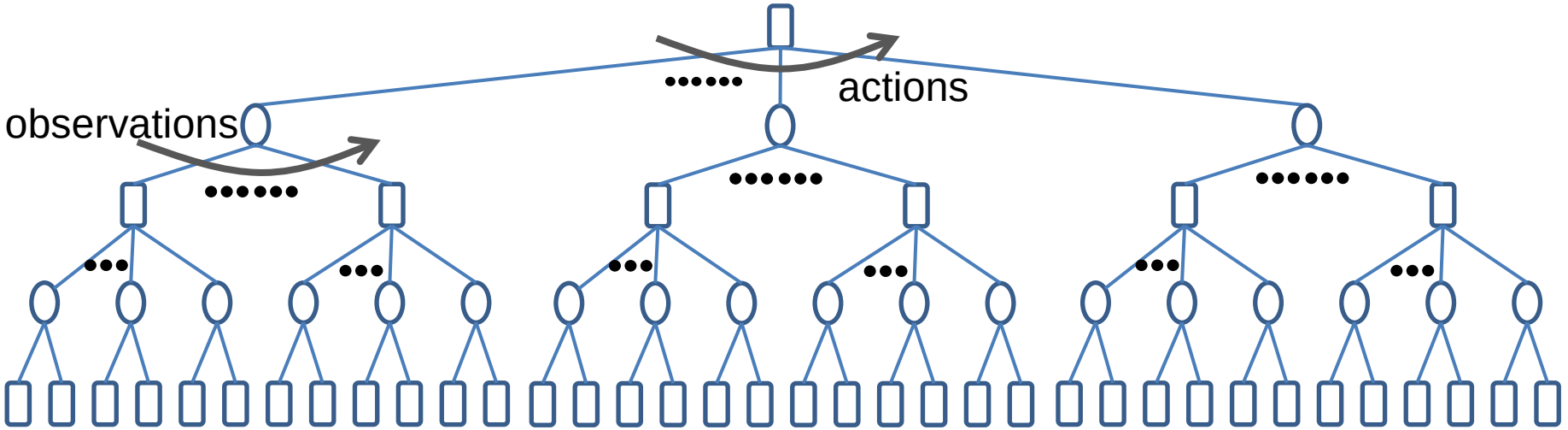
Scenario

- Motion and sensing uncertainty: Planning in information space (POMDP problem)
- Online Task Assignment
- Changes in the environment
  - Open/closed doors
  - people
- Large deviations
  - robot displacement

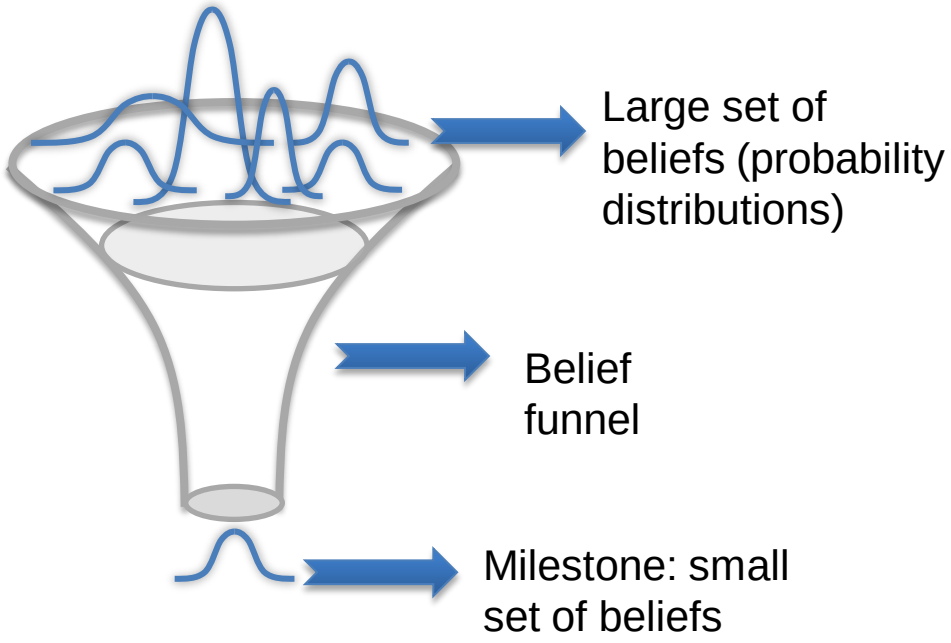
Online Replanning in information space is required

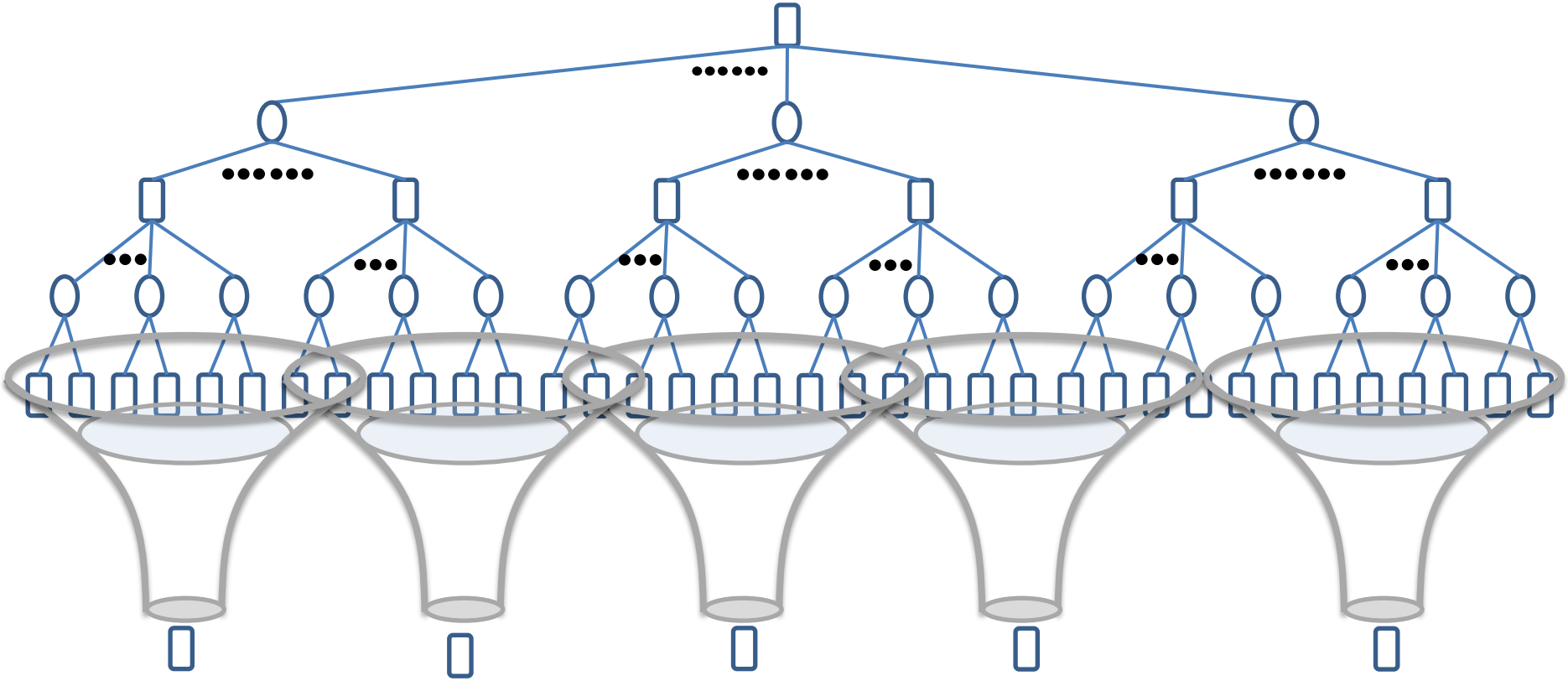


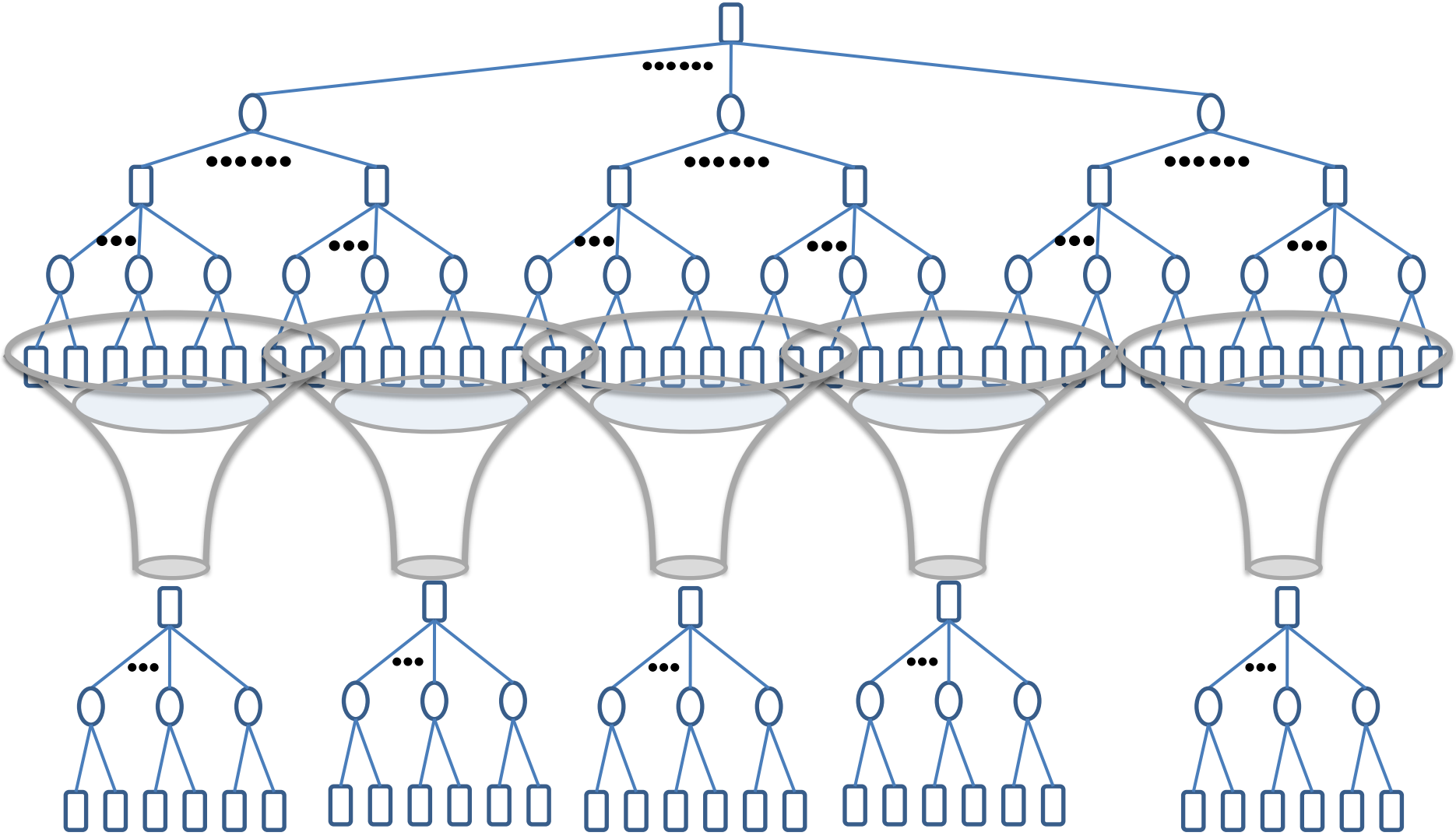


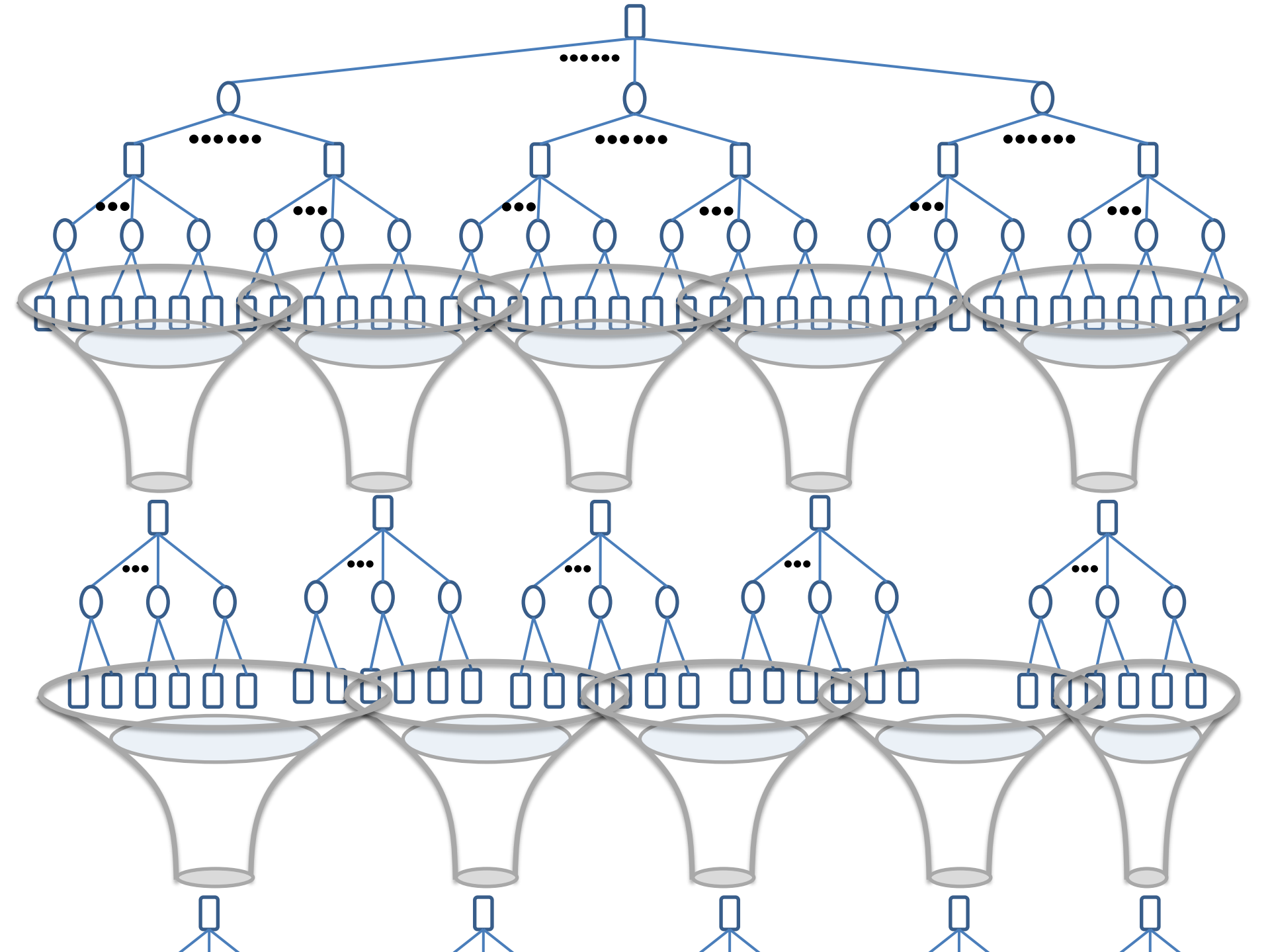


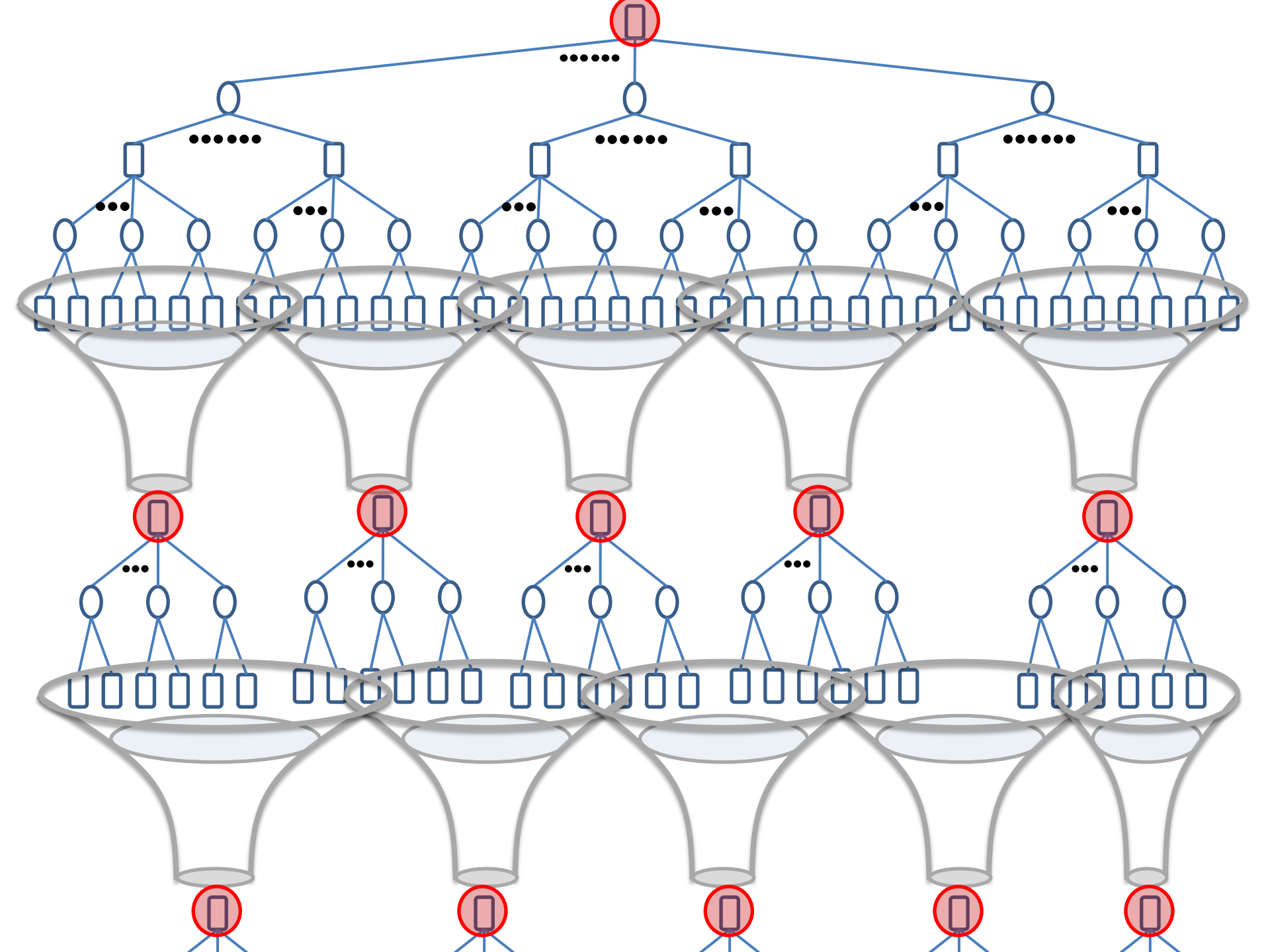
- Challenges
  - Exponential growth
  - Single-query

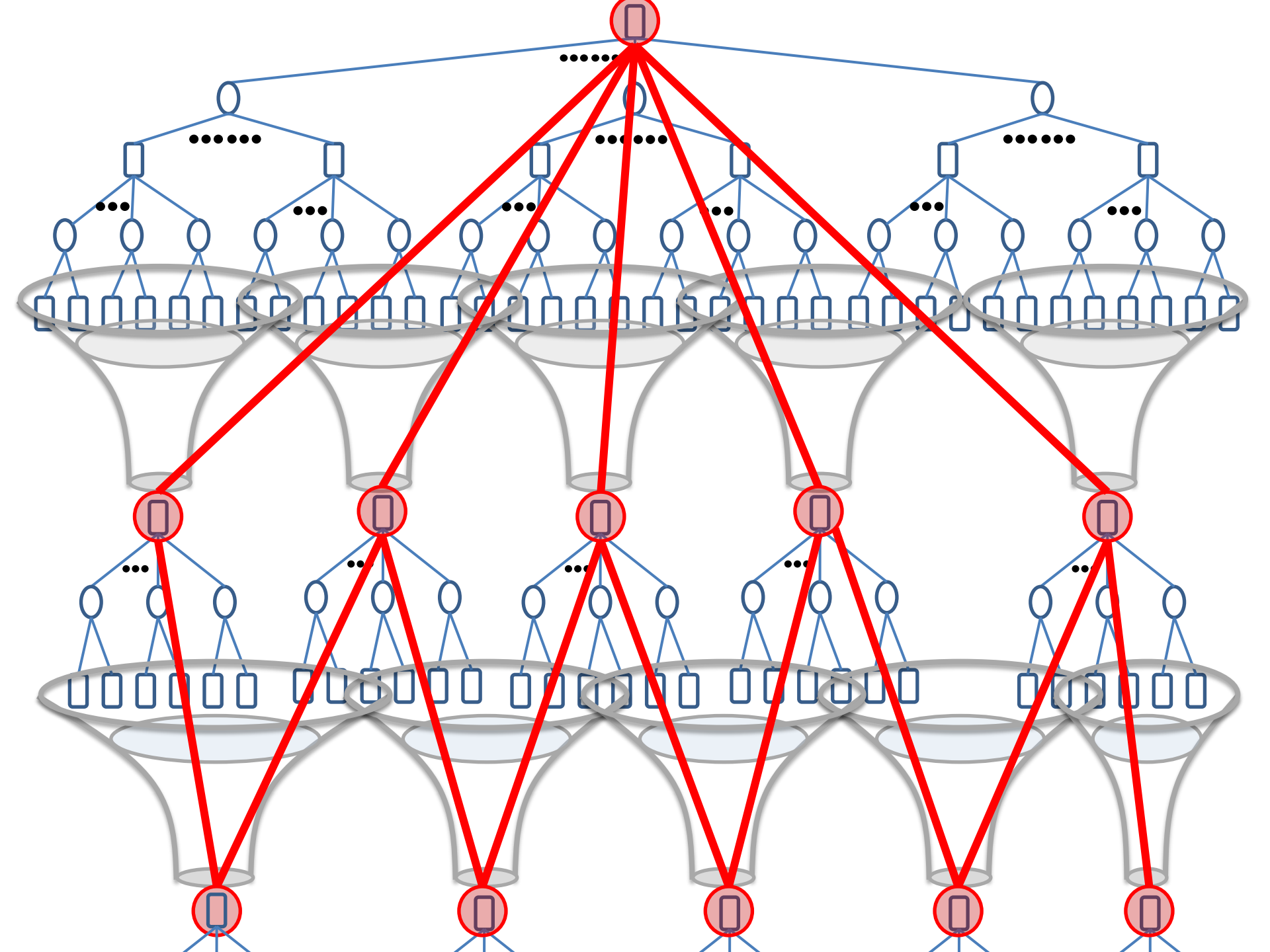












Dynamic Replanning in Belief Space

A "Rollout policy" in belief space is developed

- Uses graph as a base policy to approximate the cost-to-go beyond horizon
- Considers all possible observations in the planning horizon
- Online computations are feasible

where:

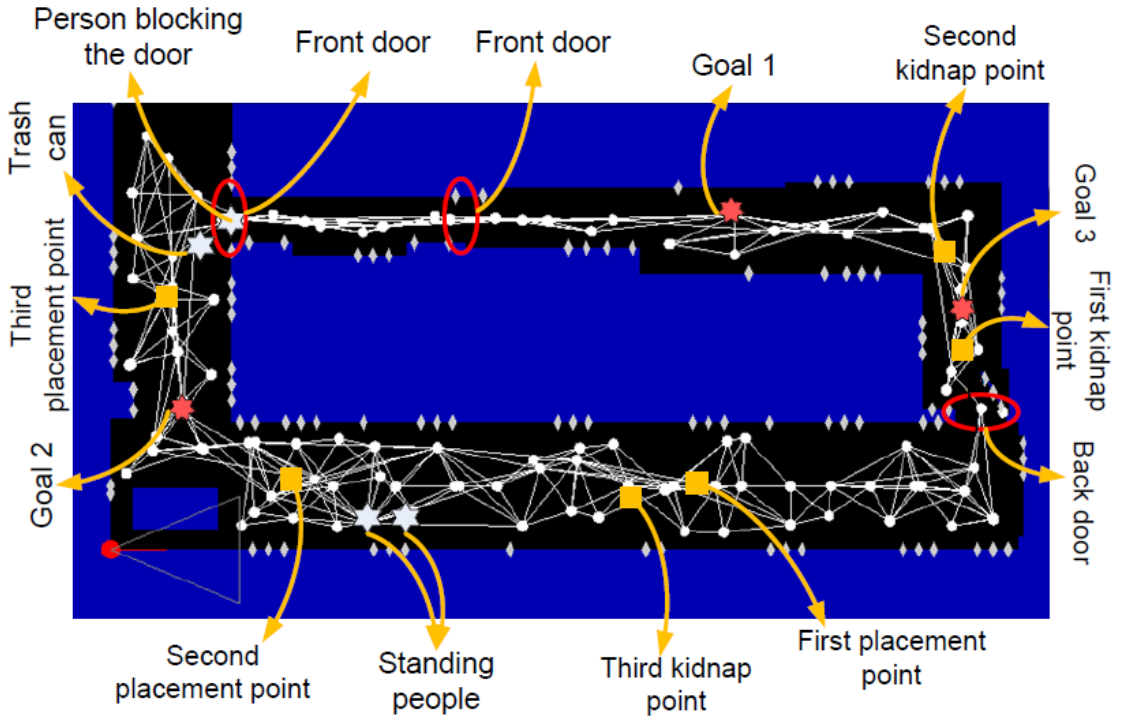
$$\pi_{0:\infty}(\cdot) = \arg\min_{\Pi} \mathbb{E}\left[\sum_{k=0}^{\mathcal{T}} c(b_k, \pi_k(b_k)) + \widetilde{J}(b_{\mathcal{T}+1})\right]$$
$$s.t. \quad b_{k+1} = \tau(b_k, \pi_k(b_k), z_k), \quad z_k \sim p(z_k|x_k)$$
$$x_{k+1} = f(x_k, \pi_k(b_k), w_k), \quad w_k \sim p(w_k|x_k, \pi_k(b_k))$$
$$b_{\mathcal{T}+1} \in \cup_j B^j,$$

$$\widetilde{J}(b_{\mathcal{T}+1}) = J^g(B^j), \quad \forall\ b_{\mathcal{T}+1} \in B^j$$

Cost-to-go of milestones are computed offline using a dynamic programming procedure

A Long and complex experiment: Video

- Robustness:
  - Three sequential goals
  - Four additional static obstacles
  - Three change in the doors' state
  - Many landmarks missing
  - Three kidnappings



Thank you!

Please come see our poster and video at the poster session!