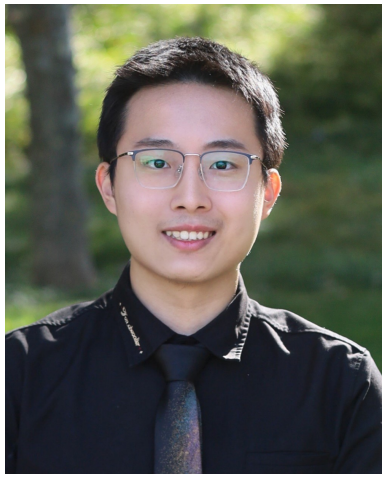
Non-Monetary Mechanism Design without Distributional Information: Using Scarce Audits Wisely

Yan Dai[1] Moïse Blanchard[2→3] Patrick Jaillet[1]



[1]MIT [2]Columbia [3]Georgia Tech

Challenge: Resource Allocation to Strategic Agents

1. **One central planner** maximize social welfare
2. K **strategic agents** self-interested (*i.e.*, may lie)
3. 1 **indivisible item**

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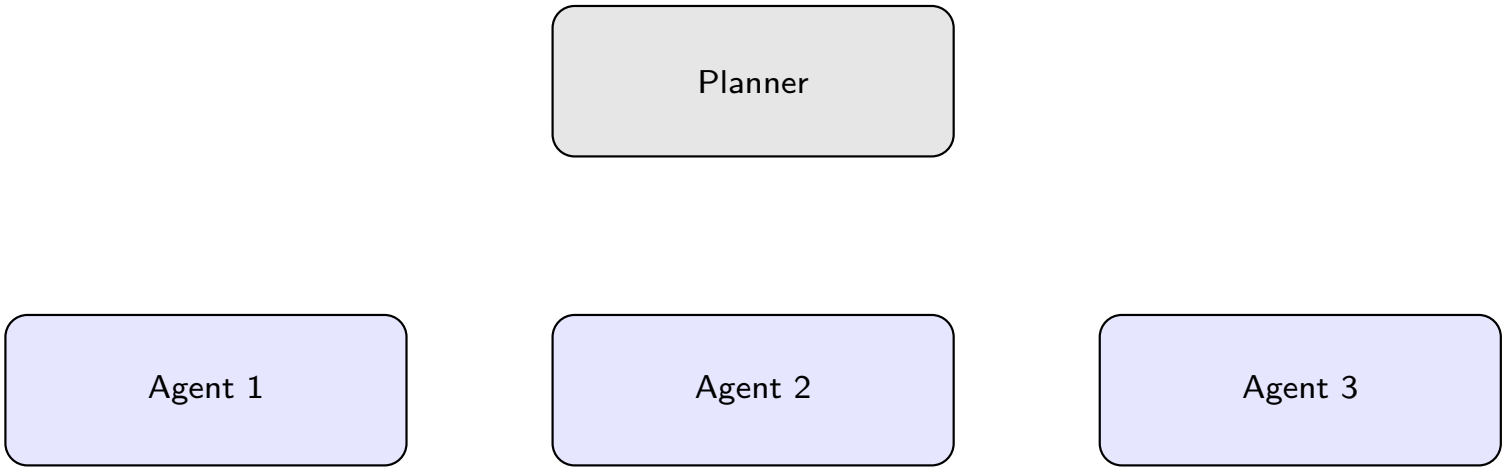

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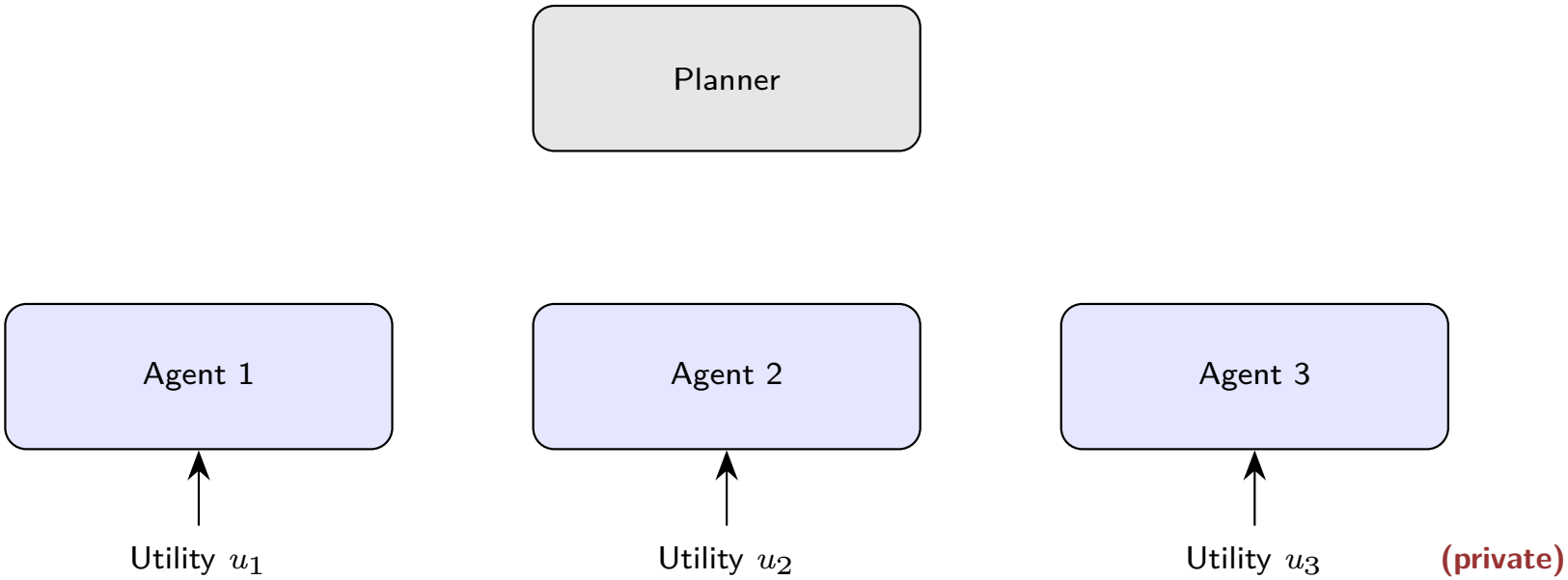

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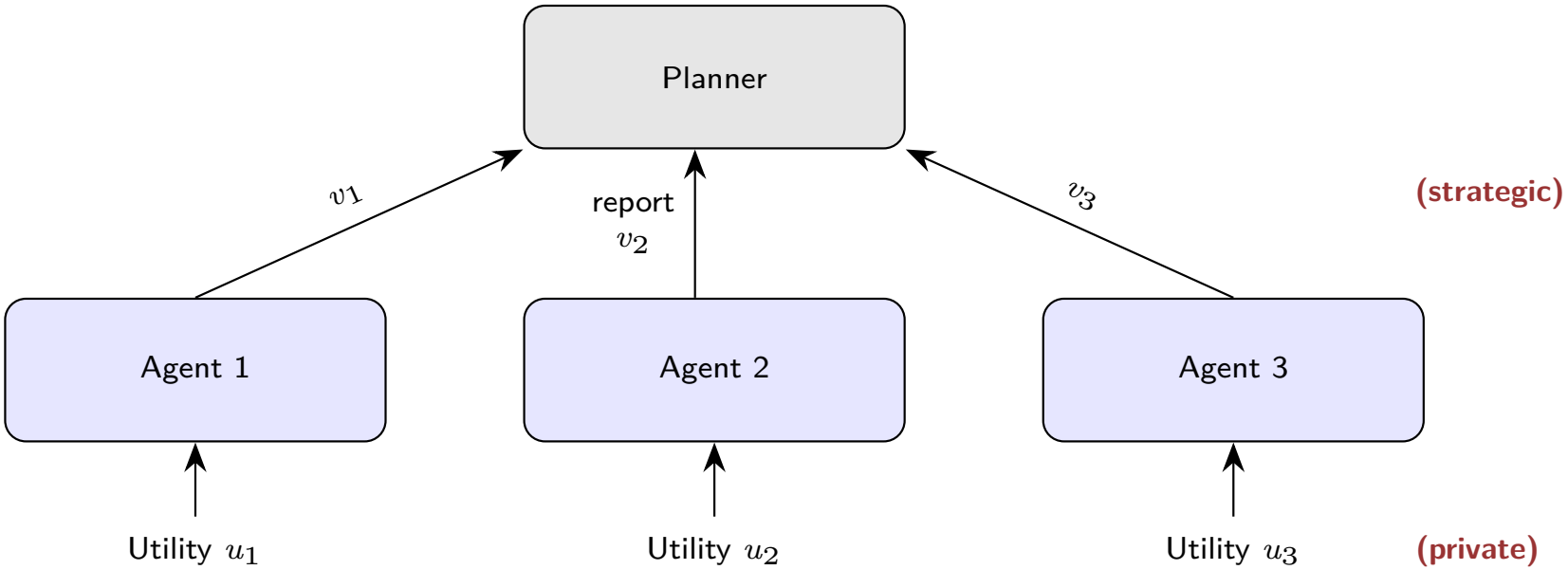

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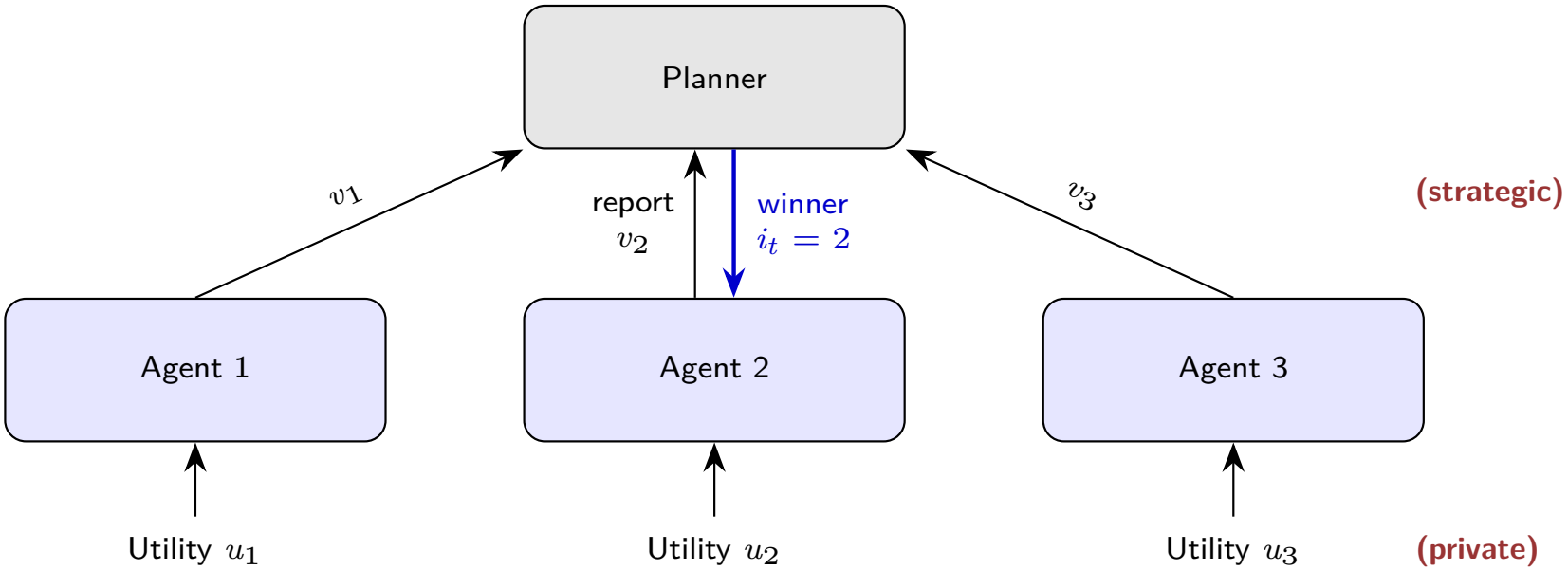

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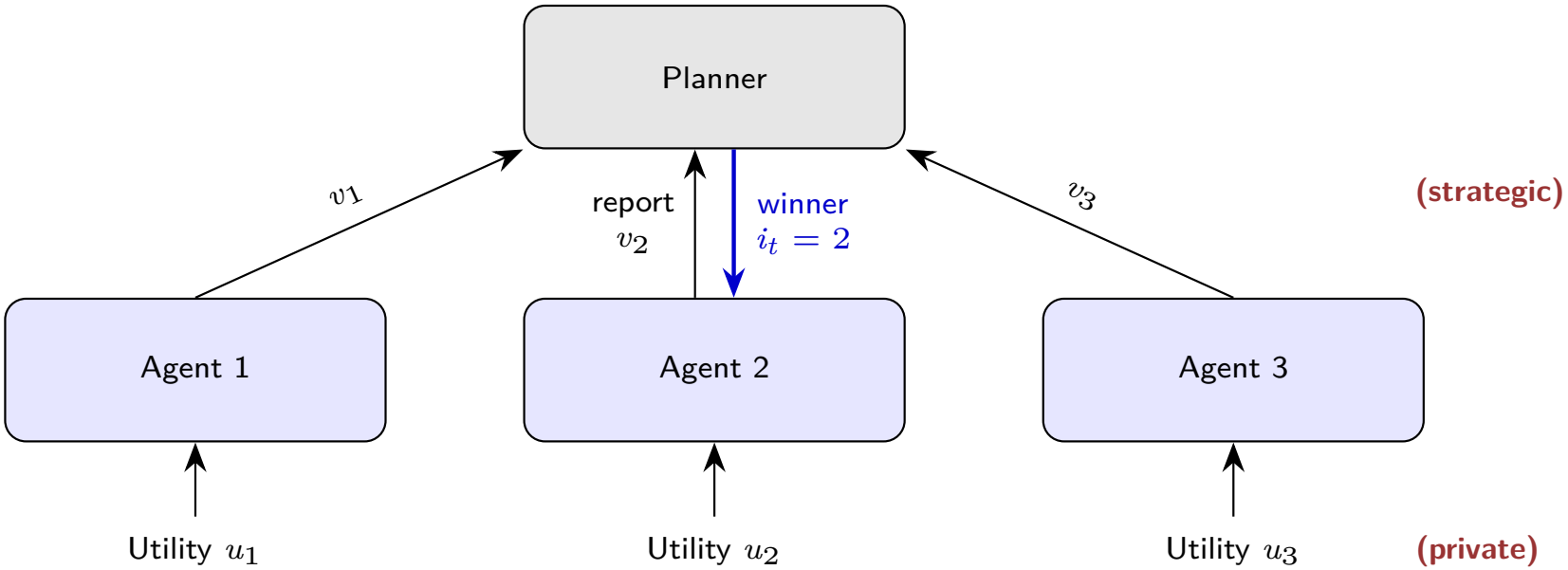

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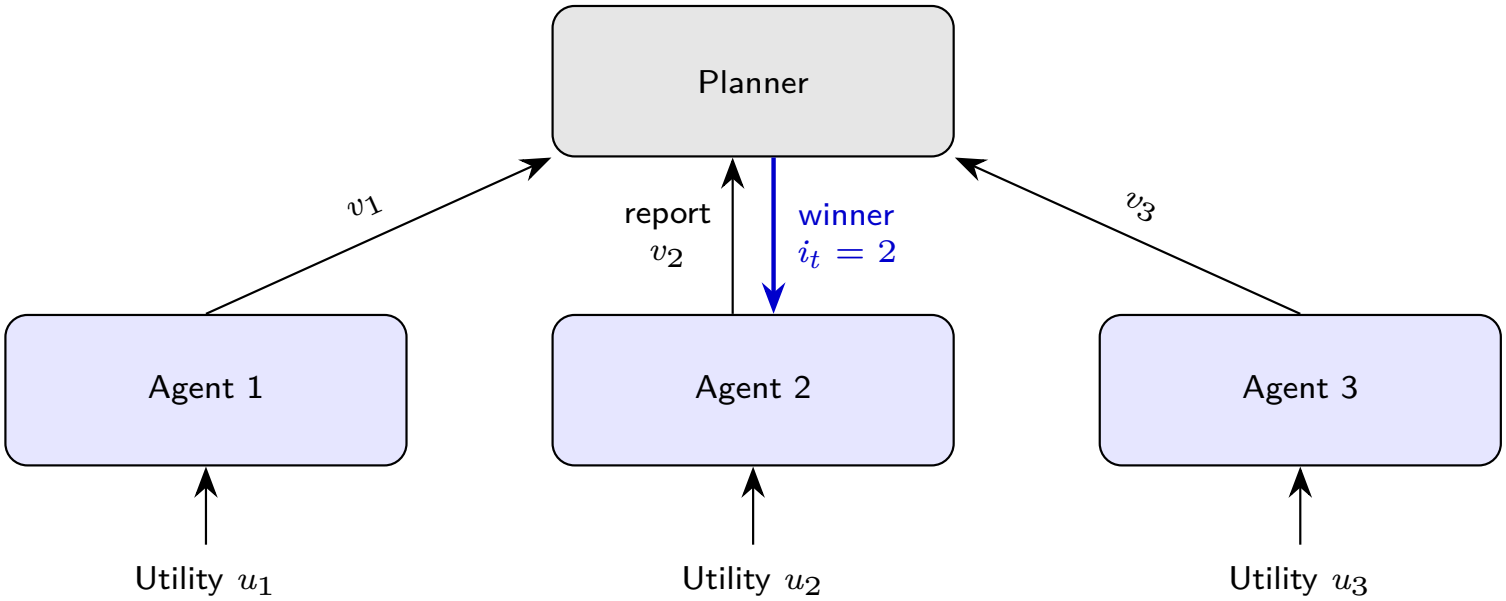
Two Objectives

Efficiency. max established utility u_{i_t} (unknown!)
Incentive-Compatibility. truthfully report $v_i \approx u_i$

Classical VCG Mechanisms



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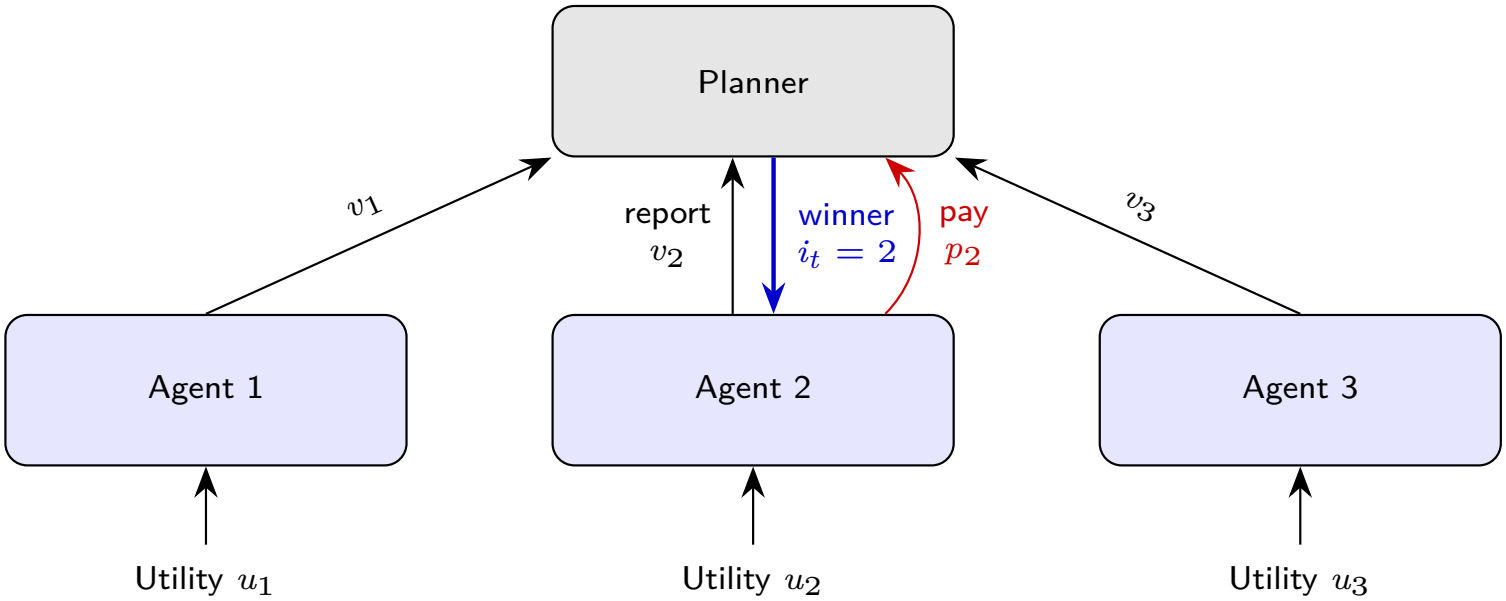

Monetary mechanisms: VCG family [Vic61; Cla71; Gro73]

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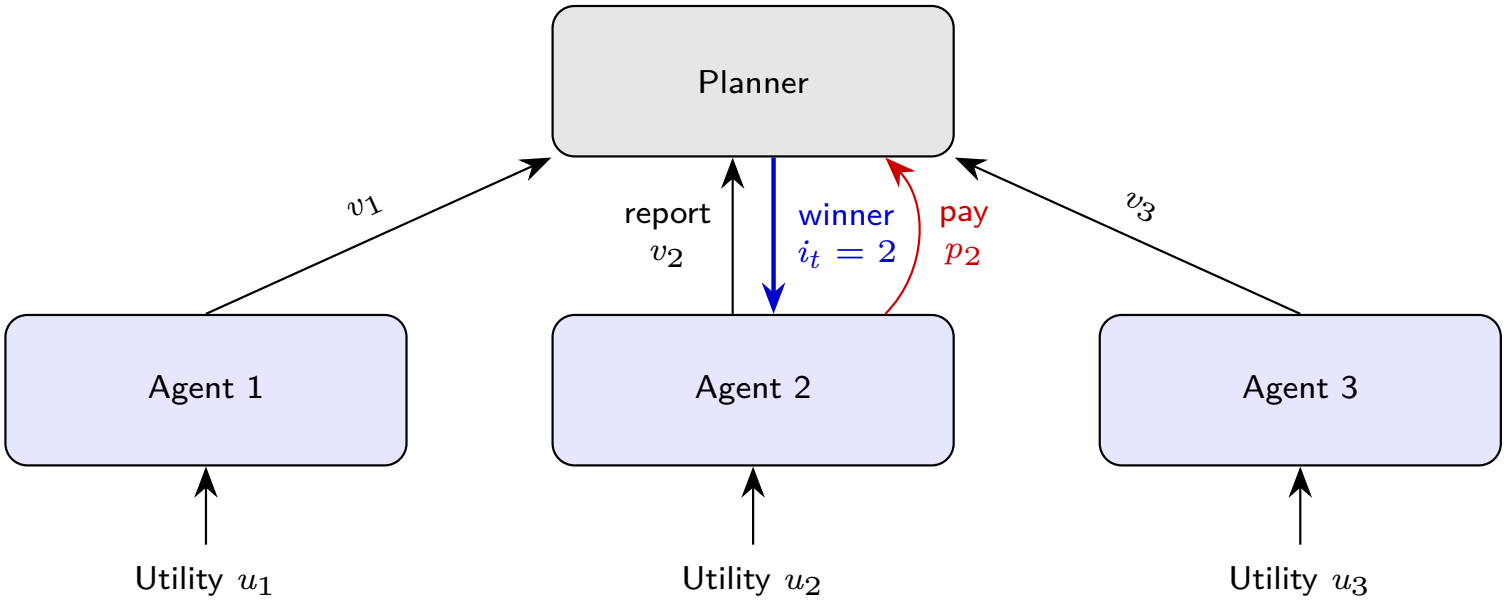

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Money isn't everything!

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3. GPU in company [ABDVVW22; PSMST22]

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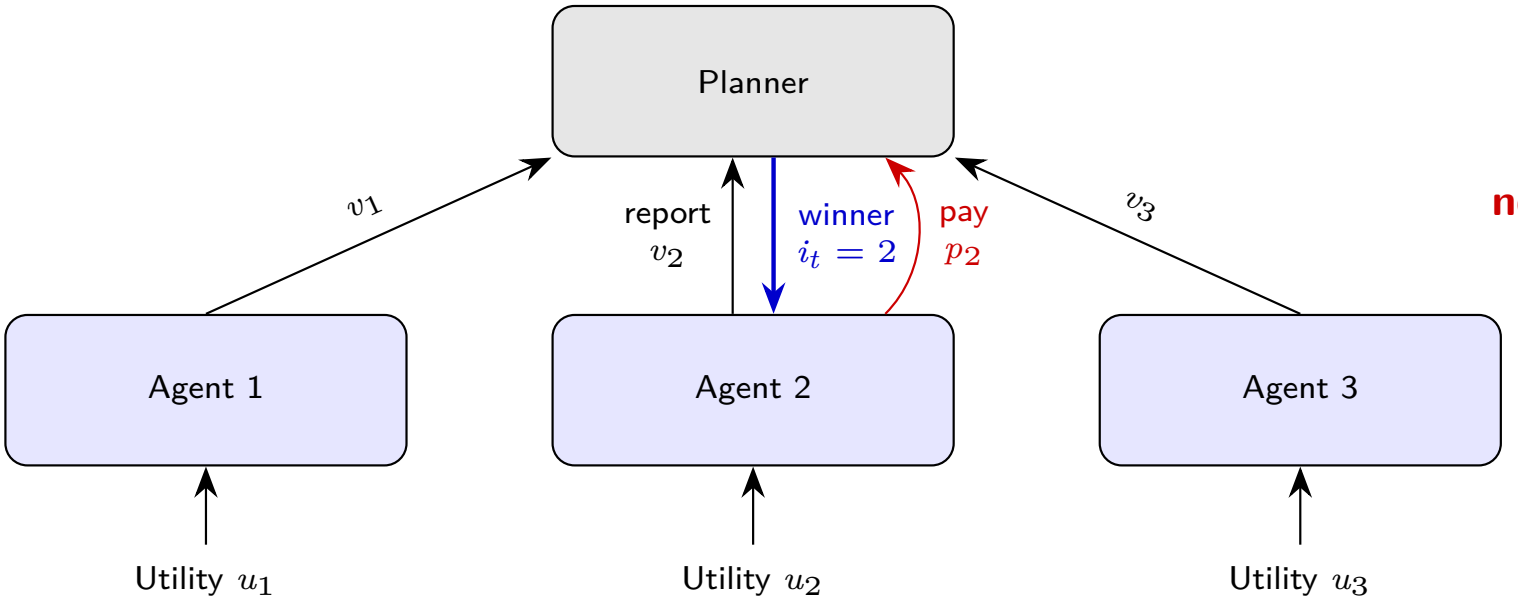

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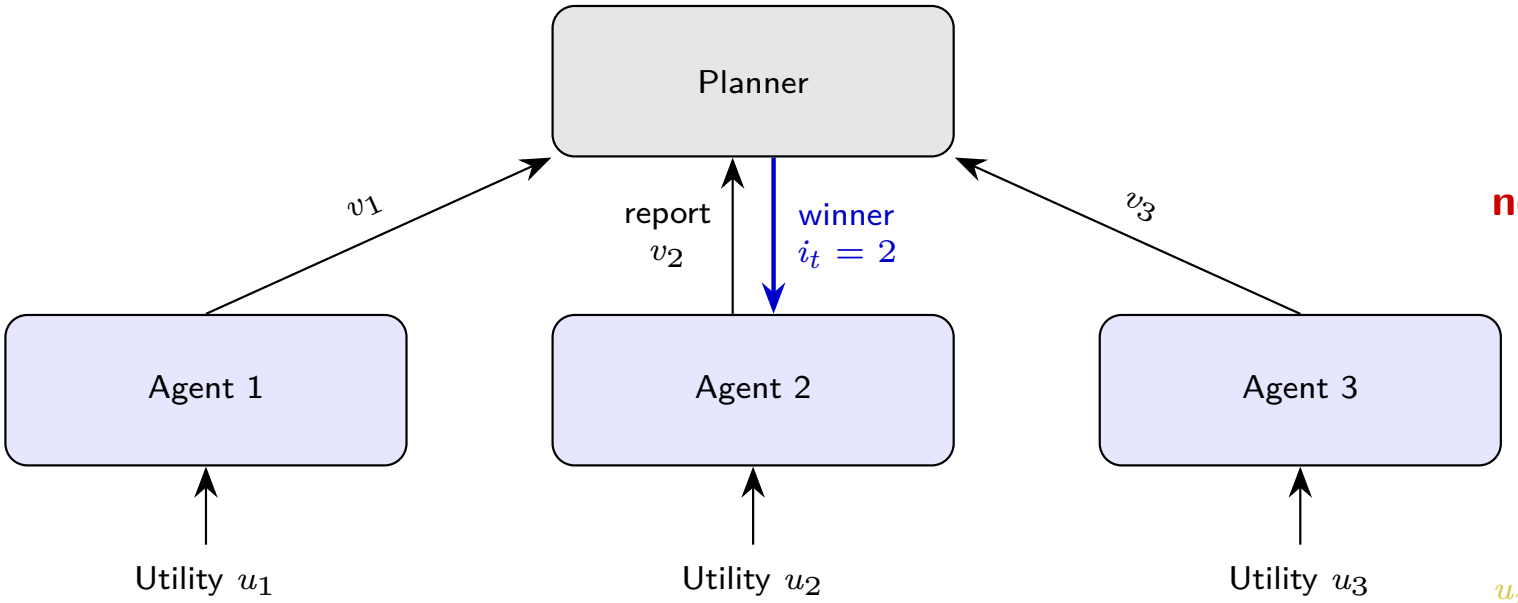

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$u_i \overset{i.i.d.}{\sim} \mathcal{U}_i$ known

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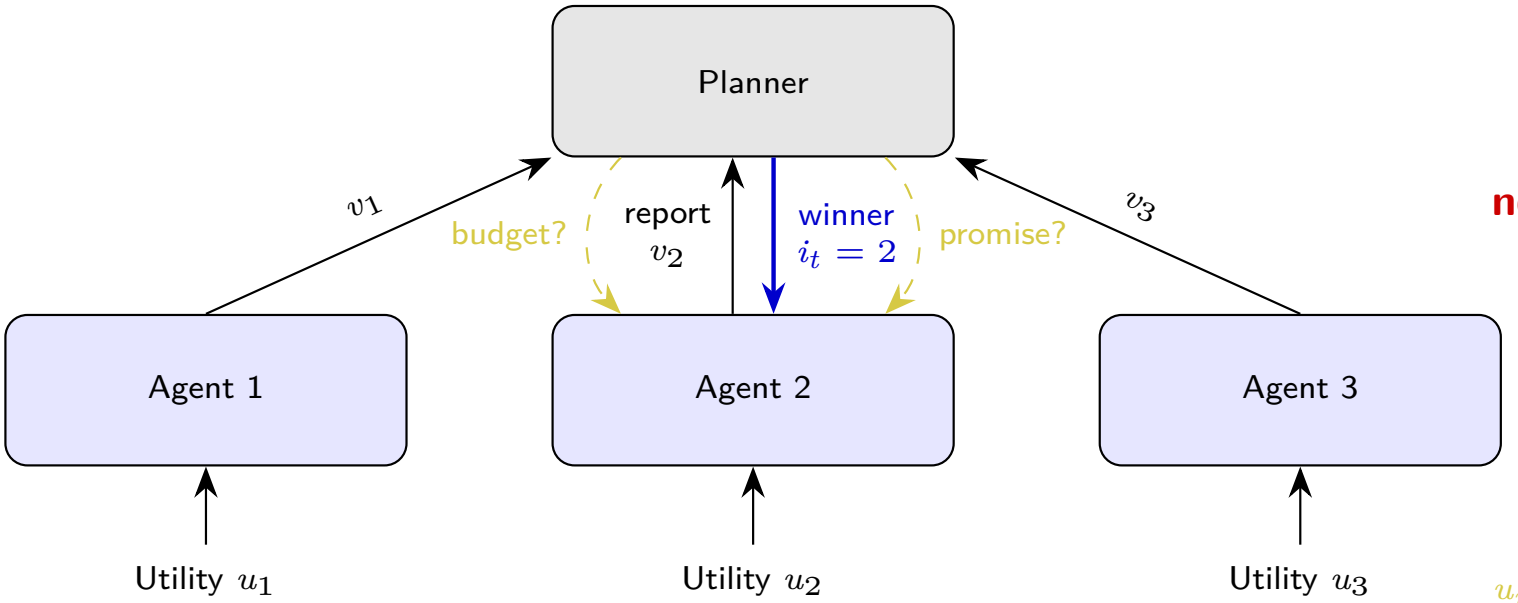

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Distribution-Aware approaches [BGS19; GBI21; BJ24]

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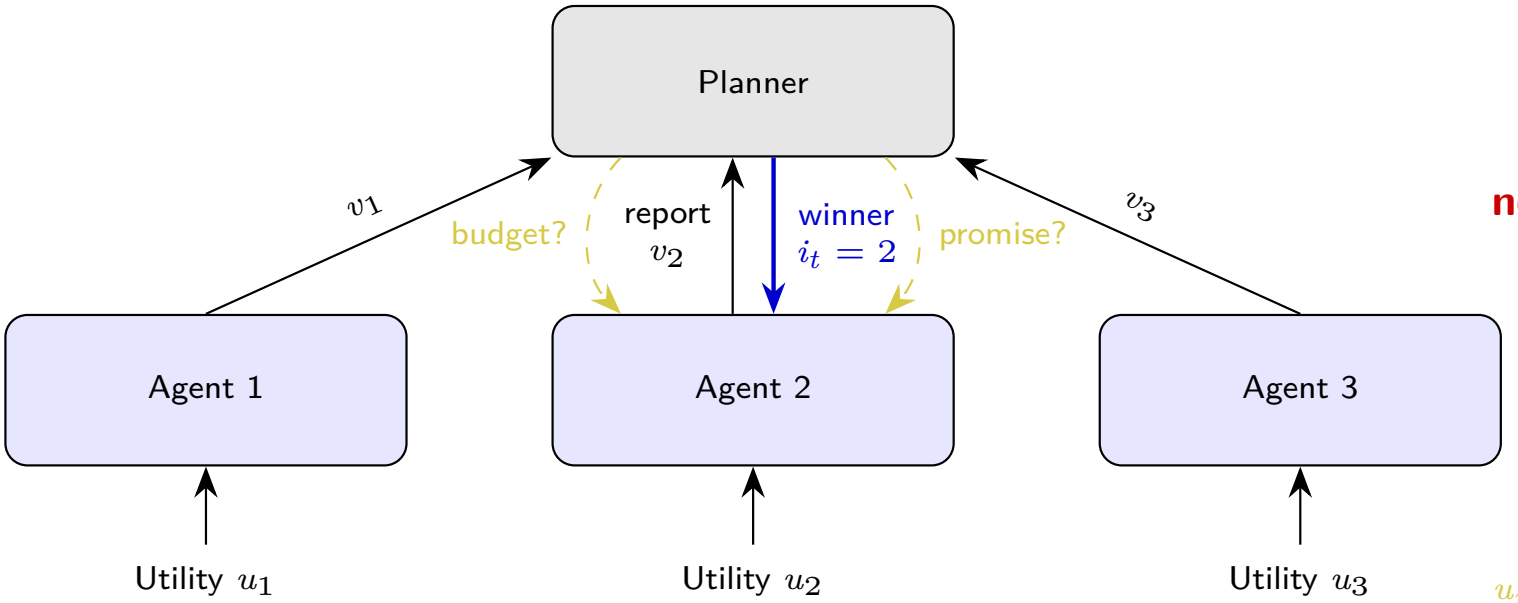

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1. Perfect knowledge on agents
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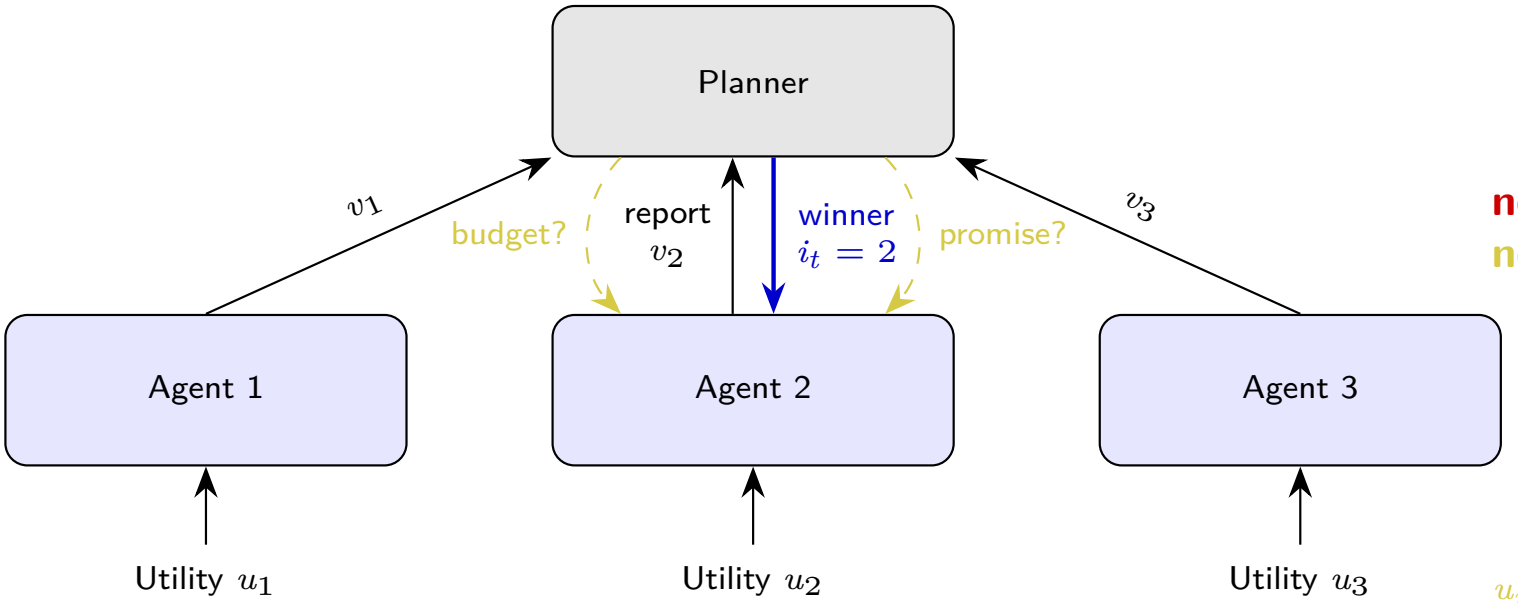

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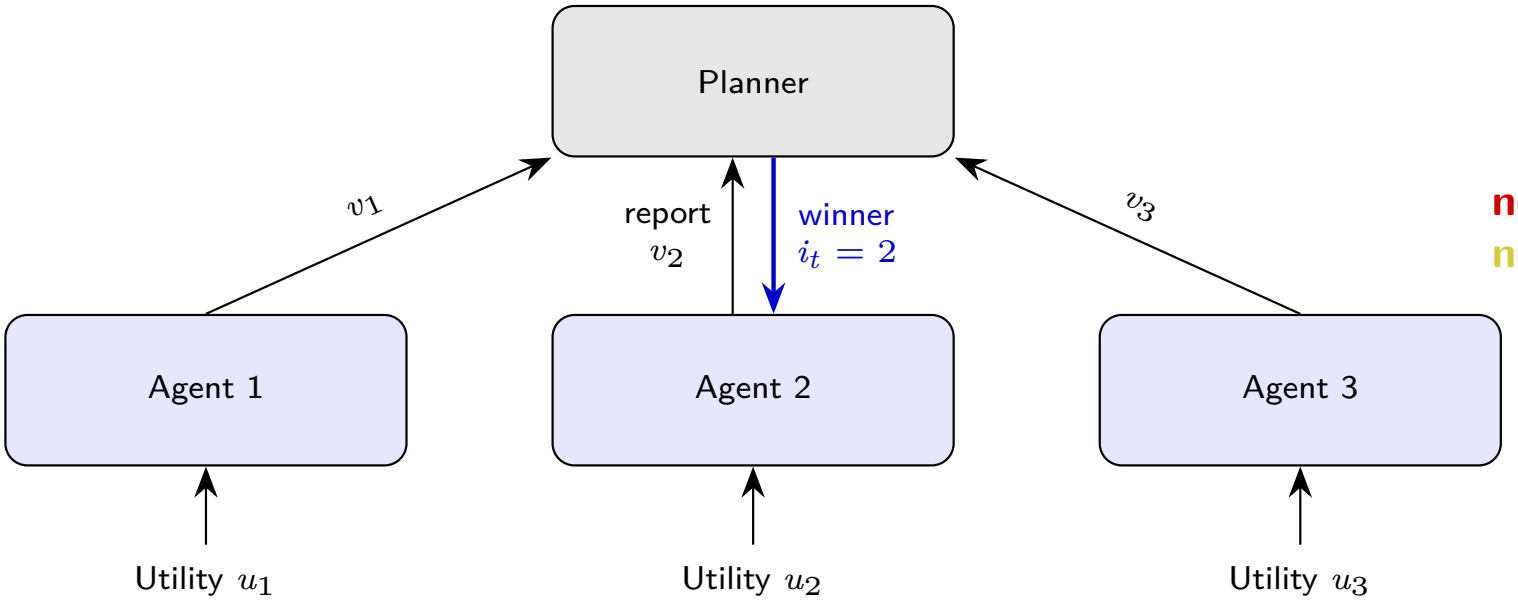

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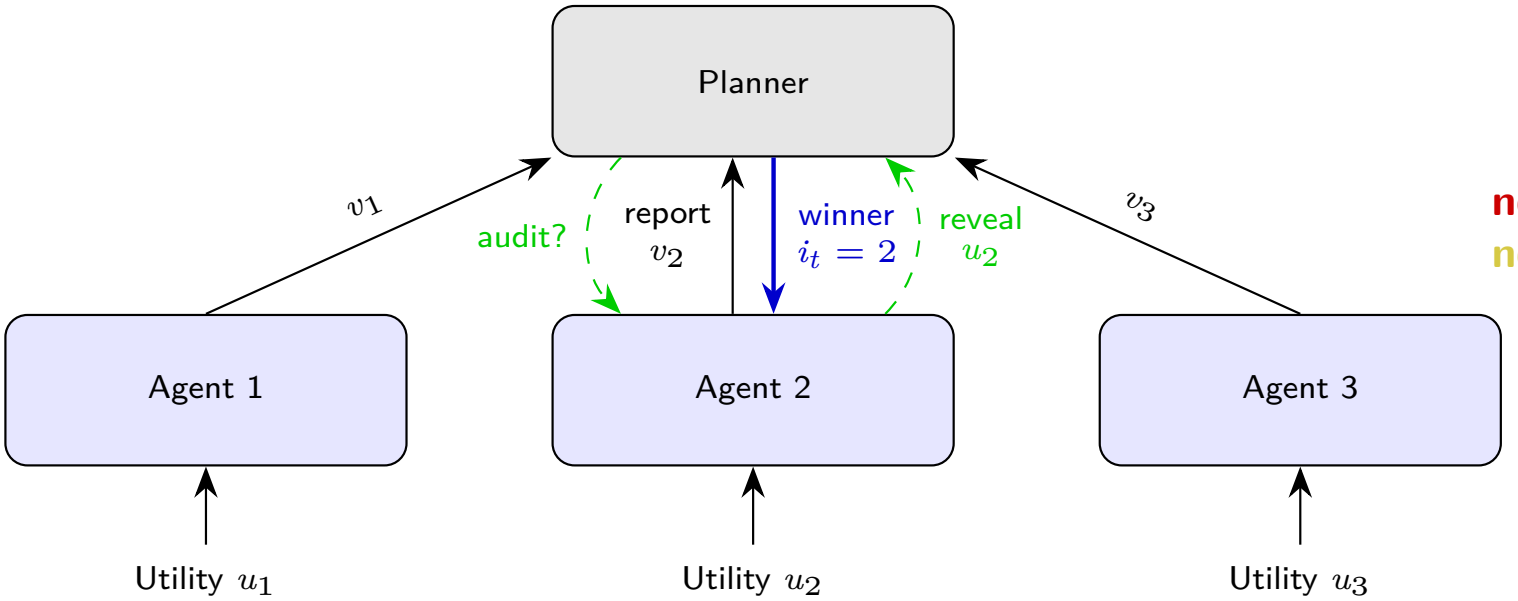

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Prior-Free mechanism via scarce & powerful "audits"

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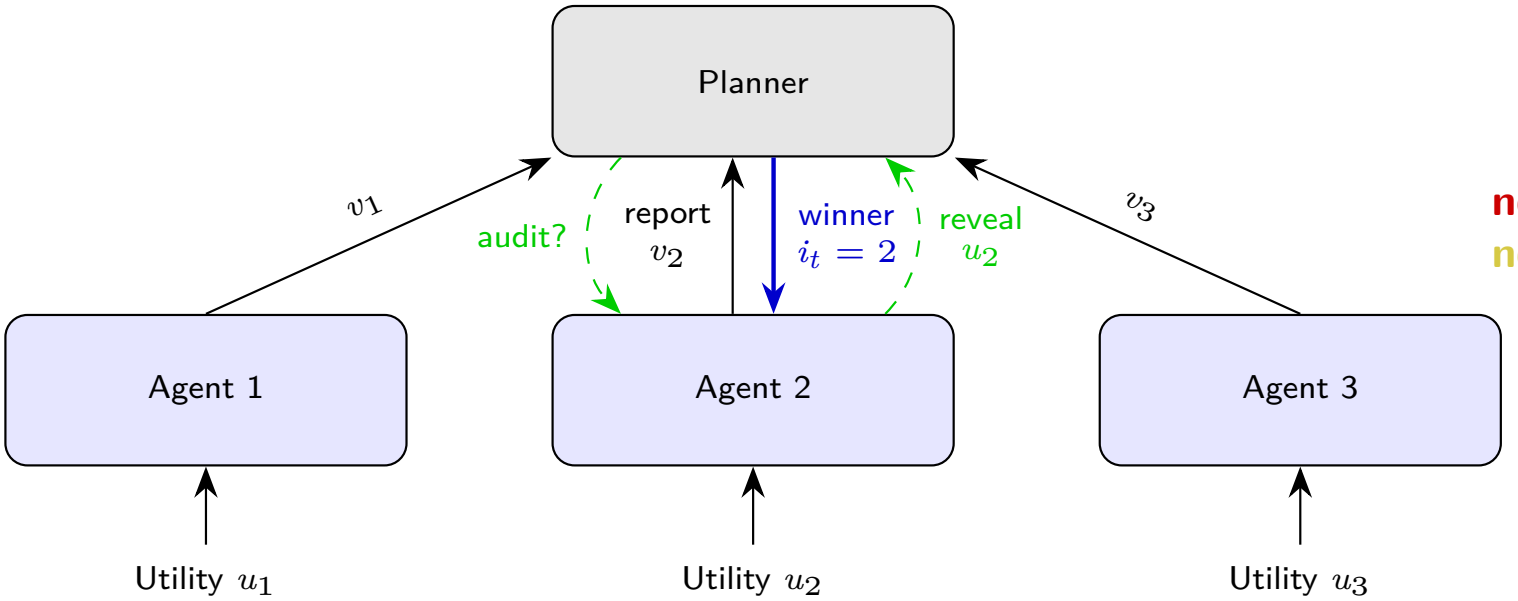

Prior-Free mechanism via scarce & powerful "audits"

Tradeoff between Regret & #Audits

Repeated allocation for T rounds:

1. **Social Welfare Regret.** $\mathcal{R}_T := \mathbb{E}[\sum_{t=1}^{T}(\max_i u_{t,i} - u_{t,i_t})]$

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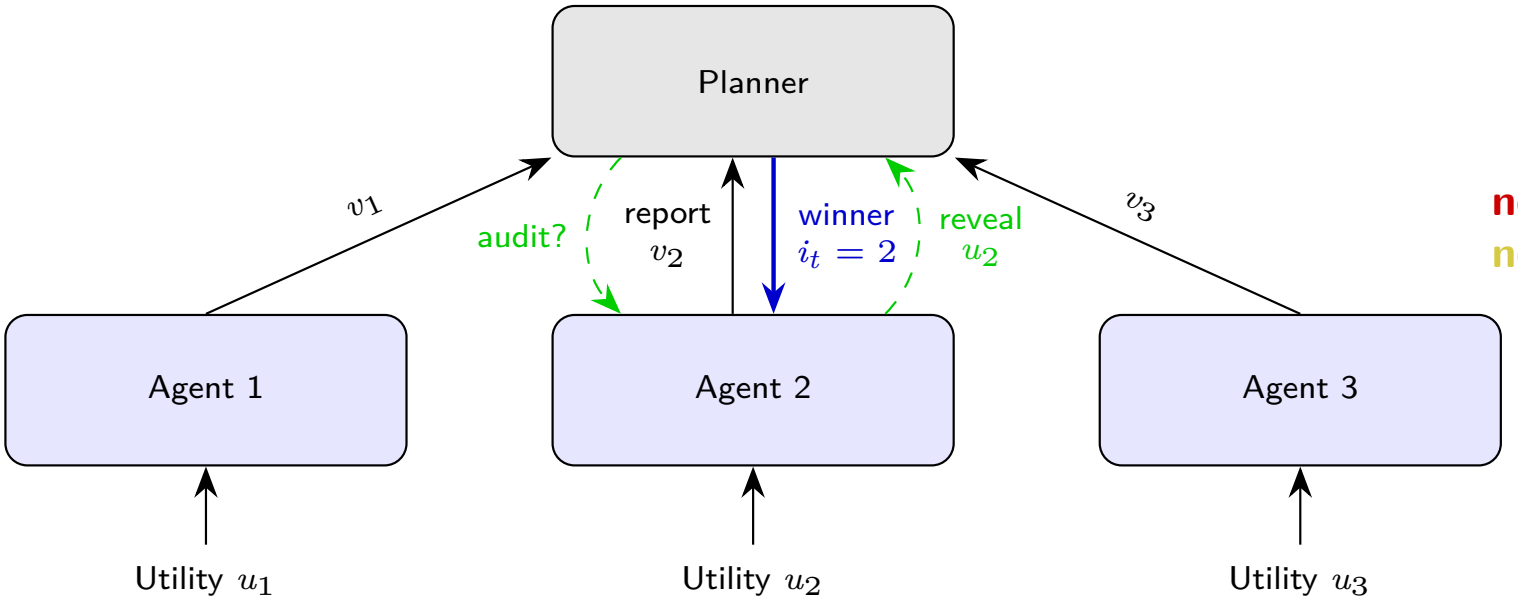

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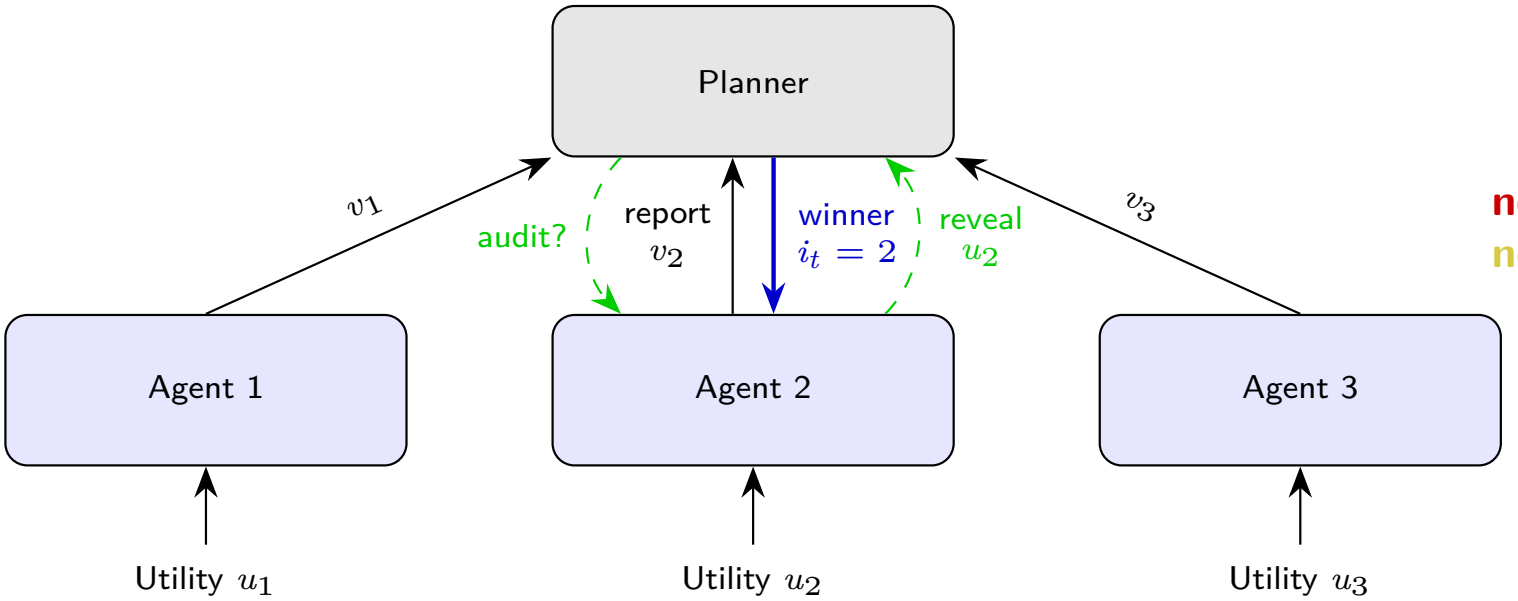

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   (Different from Online Learning regret!)
2. **Expected Number of Audits.** $\mathcal{B}_T := \mathbb{E}[\sum_{t=1}^{T} \mathbb{1}[\text{audit}]]$

Tradeoff between Regret & #Audits

$\exists$ Perfect Bayesian Equilibrium (PBE) π^*, *s.t.*

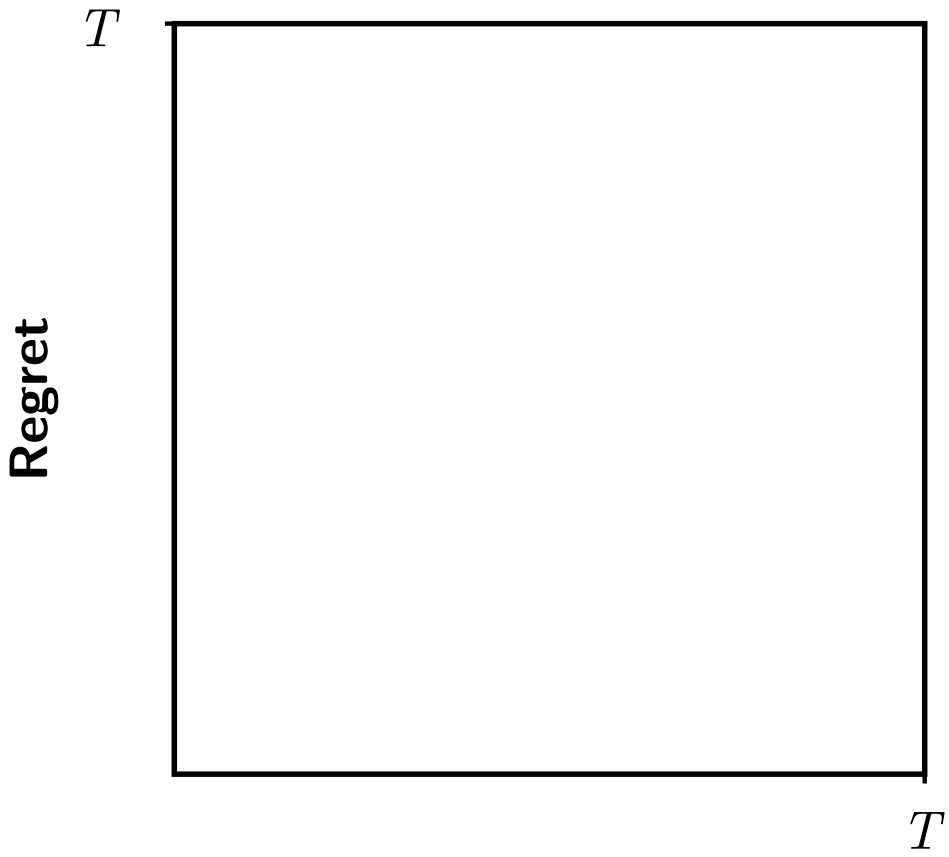

Figure: Regret vs $\mathbb{E}[\#\text{audits}]$

green possible; red impossible

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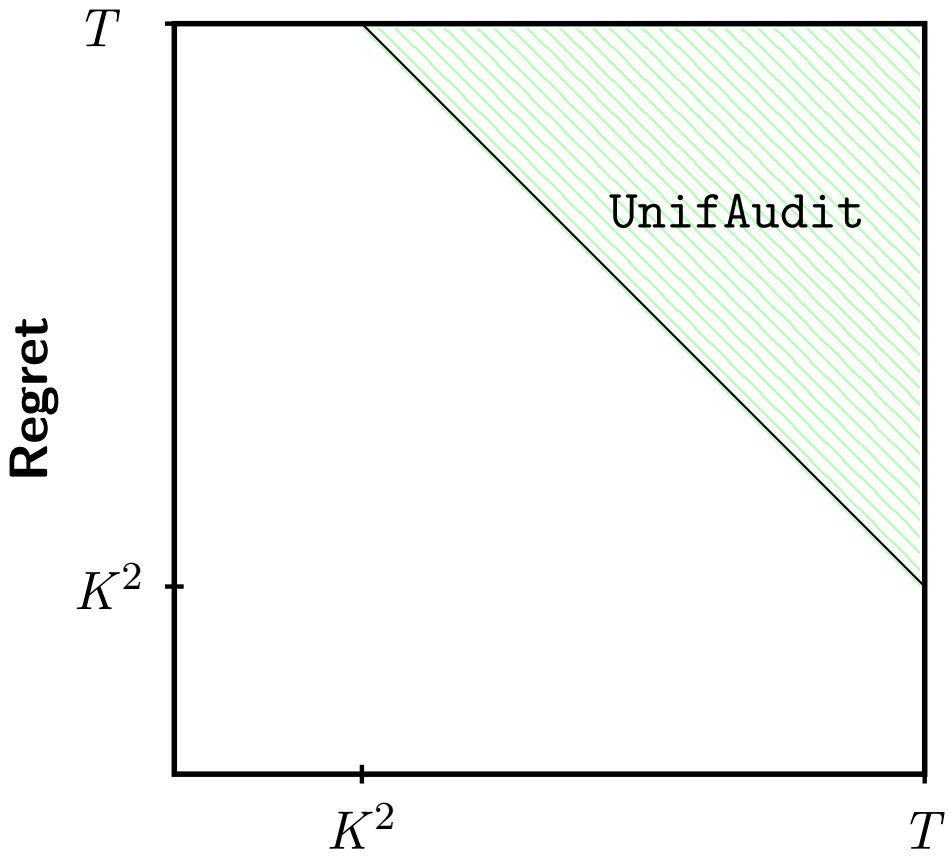

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Simple Mechanism:

`UnifAudit`.

$\mathcal{R}_T \leq \frac{K^2}{p}$ &

$\mathcal{B}_T \leq pT$.

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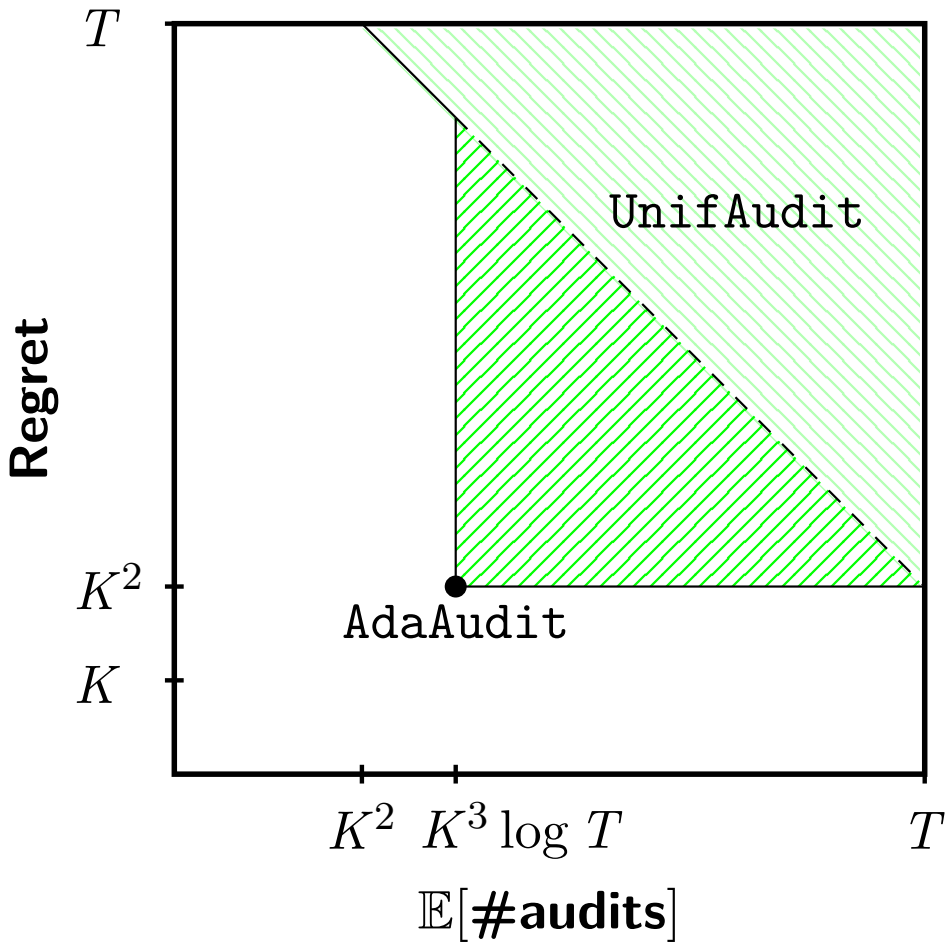

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Main Mechanism:

`AdaAudit`.

$\mathcal{R}_T \leq K^2$ &

$\mathcal{B}_T = \mathcal{O}(K^3 \log T)$.

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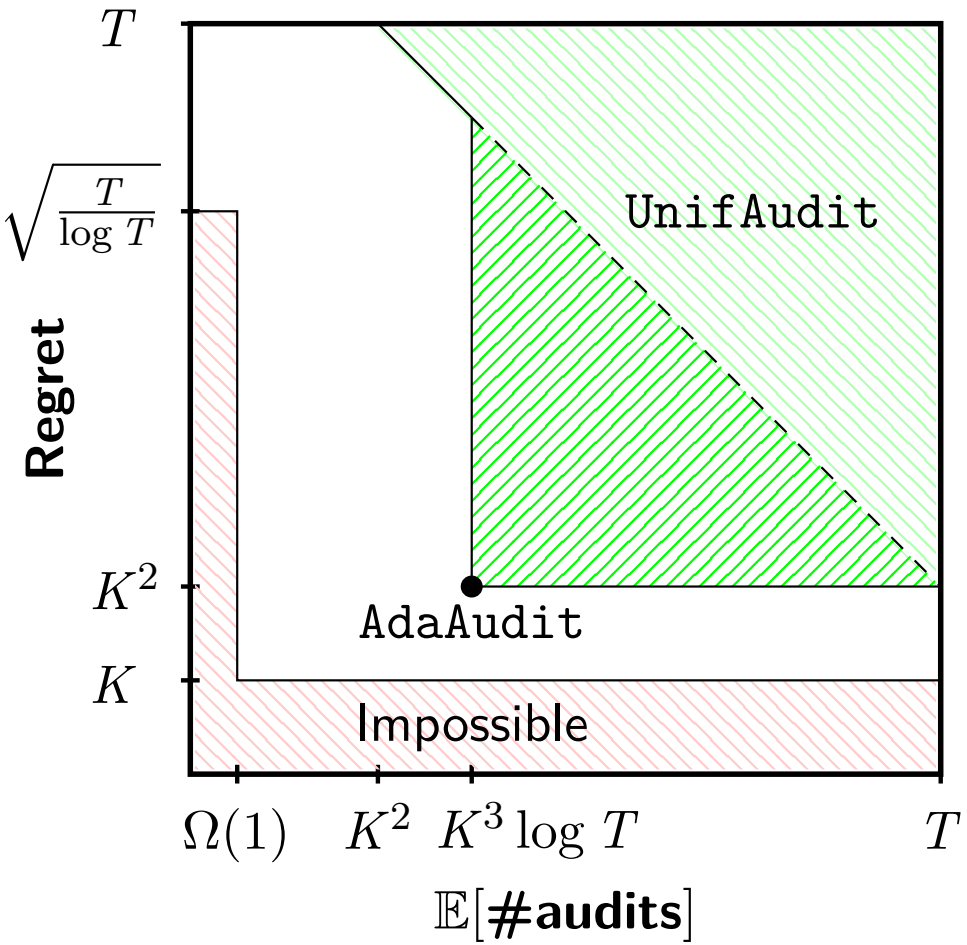

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Impossible.

$\mathcal{R}_T = \Omega(K)$;

$\mathcal{B}_T = \mathcal{O}(1) \Longrightarrow$

$\mathcal{R}_T = \Omega\left(\sqrt{\frac{T}{\log T}}\right)$.

One-Slide Technical Overview

1. **Future Punishment.** Audit reveals $v_{t,i} \neq u_{t,i} \Rightarrow$ never alloc again
2. **Adaptive Audits.**
3. **Learn via Flagging.**
4. **Auxiliary Games.**

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($V_i^{\text{alive}} := \mathbb{E}_{\text{all agents truthful}}[\sum_{\text{future round}} \text{gain of agent } i]$)

$\Longrightarrow$ (almost) always truthful & $\mathcal{B}_T = \widetilde{\mathcal{O}}(1)$

(truthful: get $\geq 0 + V_i^{\text{alive}}$; lie: get $\leq 1 + (1 - p_{t,i})\, V_i^{\text{alive}}$)

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   Need to estimate $\mathbb{E}_{\text{all agents truthful}}[\text{gain of agent } i]$ empirically but can't "condition on" concentration
   (since agents can strategize early; happy to explain offline)
   Idea: Let agents "flag" others for biased estimates
   ("victims" benefit from truthfully flagging $\Longrightarrow$ incentives aligned)

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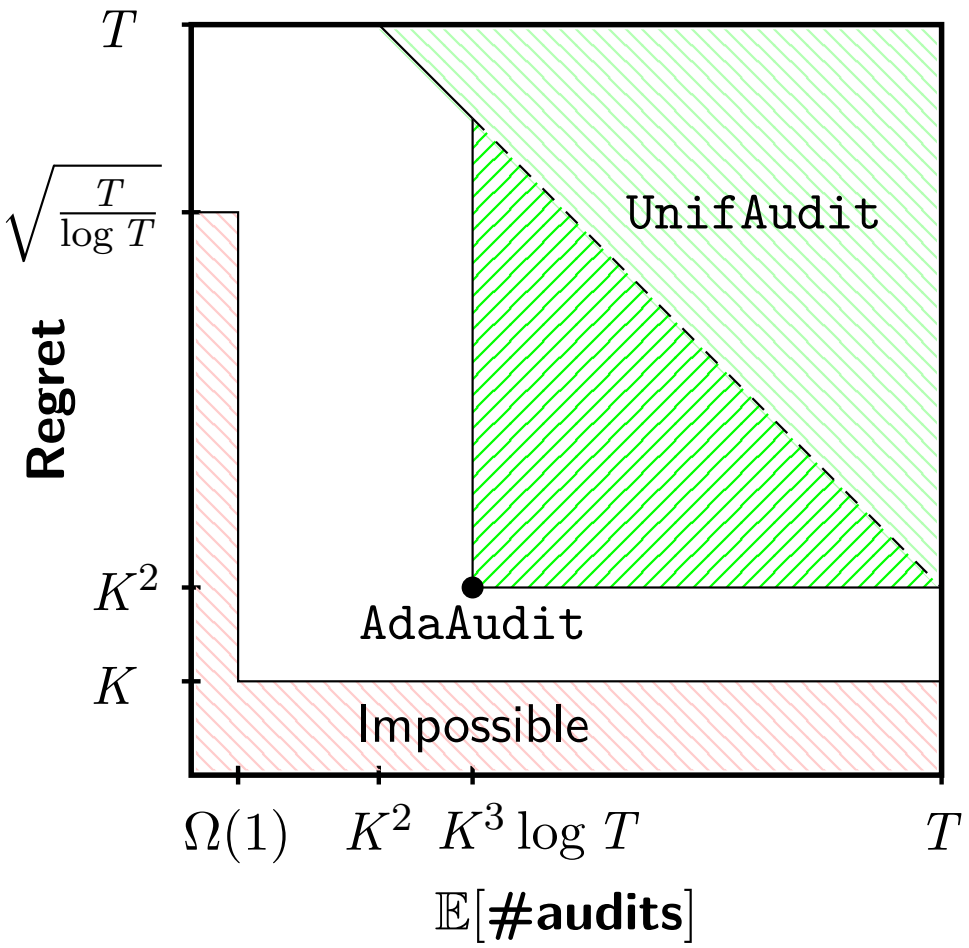
4. **Auxiliary Games.**
   Can't use revelation principle due to unknown / non-unique distributions (happy to explain offline)
   How to characterize PBE? Define a "well-behaved" aux game, show aux PBE $\overset{\text{induce}}{\mapsto}$ actual PBE

Main Results & Takeaway

For resource allocation without money & without dist info...



Technical Ingredients

- **Future Punishment**
- **Adaptive Audits** ($\mathcal{O}(1)$ regret via $\widetilde{\mathcal{O}}(1)$ audits)
- **Learn via Flagging** ("condition on" argument is problematic when strategic)
- **Auxiliary Games** (revelation principle is inapplicable w/o dist info)

Thank you!

Paper link: `https://arxiv.org/abs/2502.08412`

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