NC STATE UNIVERSITY

Nicholas Larsen*
Srijan Sengupta
Jonathan Stallrich
Department of Statistics, North Carolina State University

HODOR

A two-stage Hold-out Design for Online Randomized experiments.

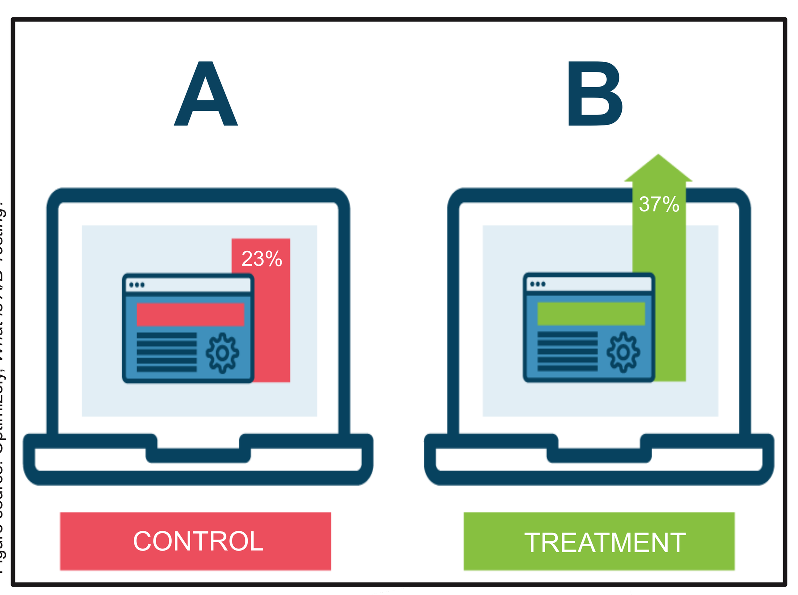
A Design for Network A/B Testing

To develop new software, products, and features, online businesses such as Facebook, Netflix, and Google deploy thousands of A/B tests per year on tens of millions of users.

Objective: Develop a simple experimental design and estimation technique for the Average Treatment Effect in network A/B testing.

- Independent of network structure.
- Accounts for unobservable features.
- Optimizable for better sensitivity.

Online Controlled Experiments



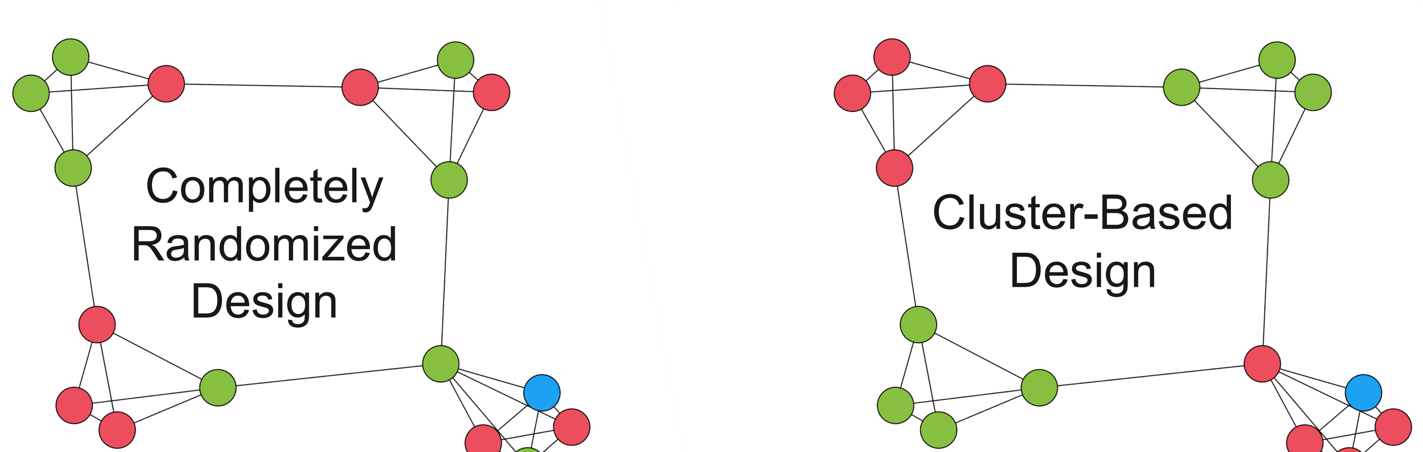
Average Treatment Effect:

$$ATE = \frac{1}{N}\sum_{i=1}^{n}\left(E[Y_i|B] - E[Y_i|A]\right)$$

$\widehat{ATE} = \bar{Y}_B - \bar{Y}_A$ is unbiased.

Key: Stable Unit Treatment Value Assumption (SUTVA) & Complete Randomization.

Challenge 1: Network Effects ⇒ SUTVA Violation



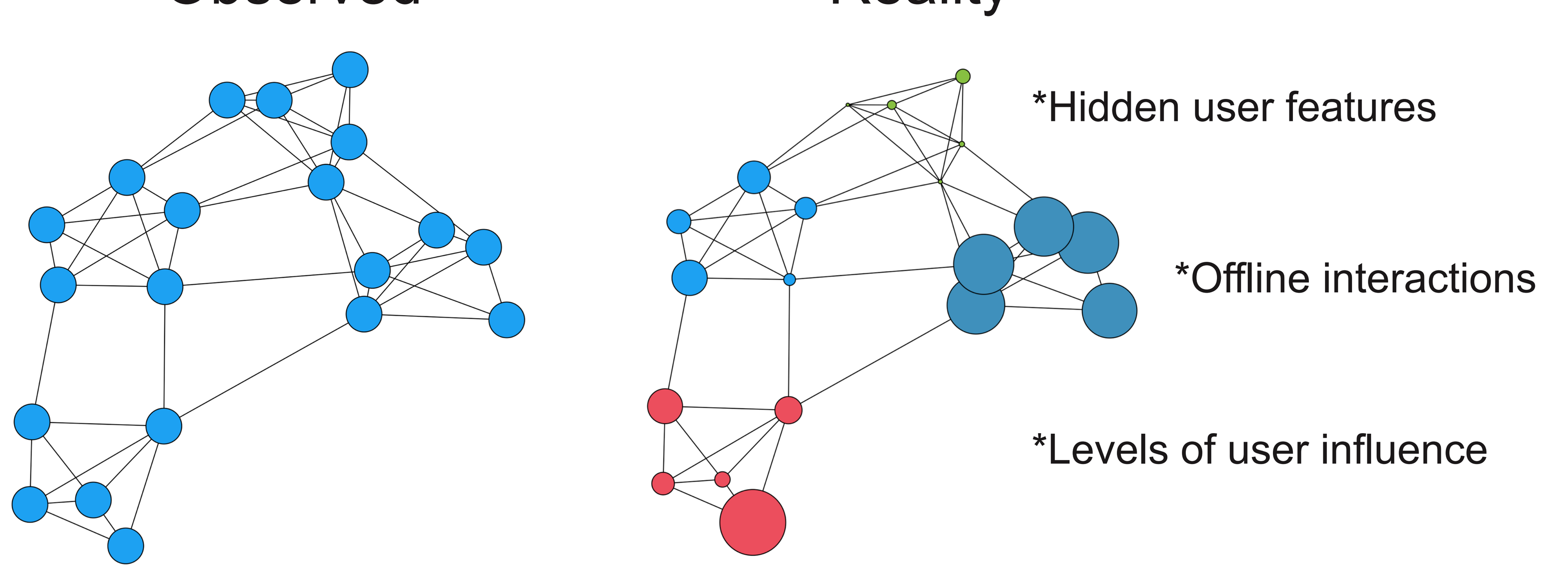
Y_i depends on both treatment and control.

Y_i depends only on control.

Challenge 2: (Partially) Unobservable Networks

Observed

Reality



Framework

$$Y_i = \alpha + \beta z_i + \gamma T_i + \delta S_i + \epsilon_i$$

- Intercept: α
- Impact of unobserved feature: β
- Unobserved covariate: z_i
- Treatment effect: γ
- Binary treatment indicator: T_i
- Spillover effect: δ
- Proportion of treated neighbors: S_i
- Noise, $E[\epsilon_i] = 0$

$$ATE = \gamma + \delta \qquad E\left[\widehat{ATE}_{crd}\right] = \gamma$$

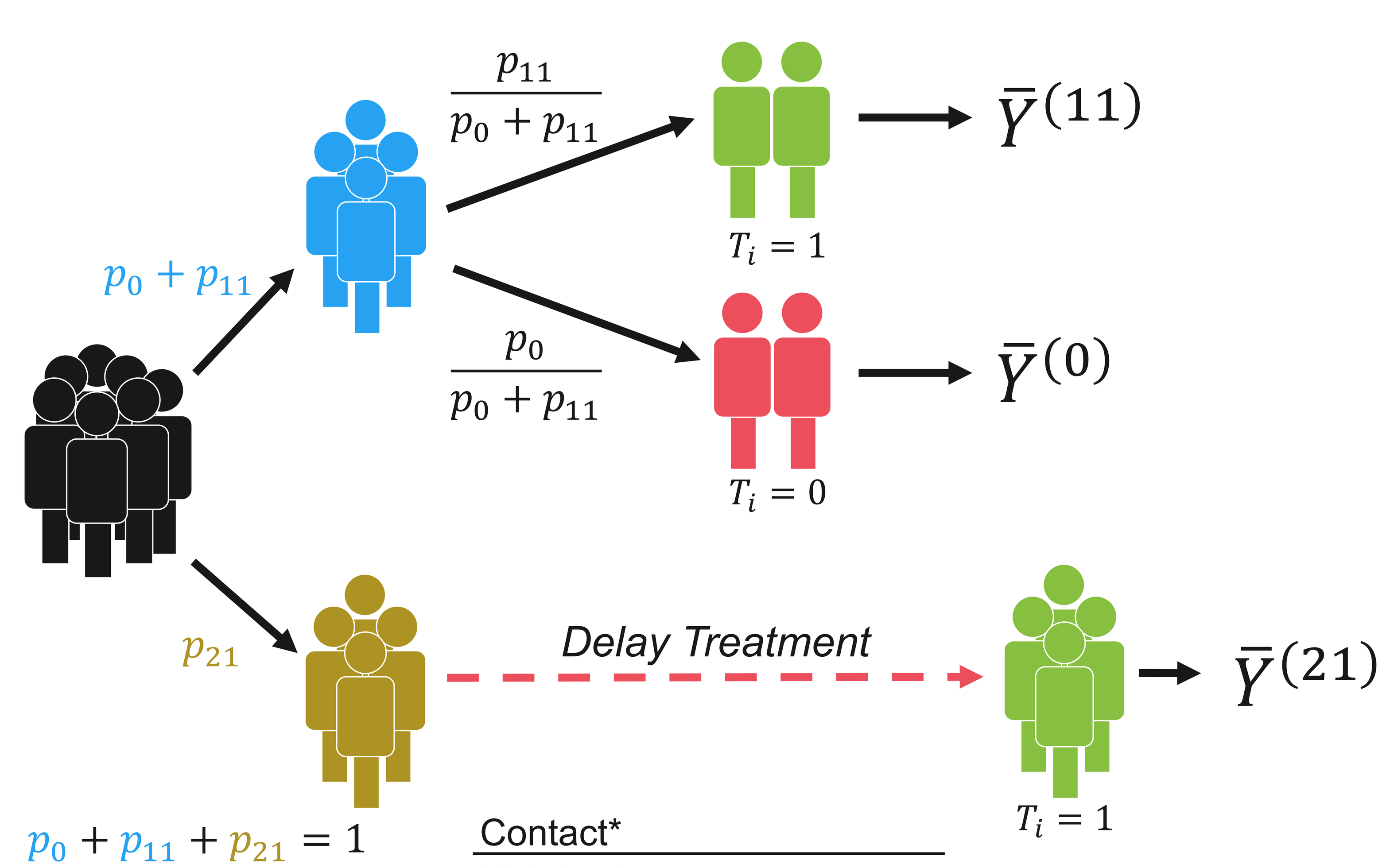
$$E\left[\widehat{ATE}_{cl}\right] = \gamma + \beta(E_1[Z] - E_0[Z]) + \delta(E_1[S_i] - E_0[S_i])$$

Current ATE estimators under SUTVA violation require full knowledge of the network and presume $\beta = 0$.

An Estimator Independent of Network Structure

$$\underbrace{\widehat{ATE}}_{\text{HODOR}} = \underbrace{\left(\bar{Y}^{(11)} - \bar{Y}^{(0)}\right)}_{\text{Stage 1: Estimates } \gamma} + \underbrace{(p_{21})^{-1}\left(\bar{Y}^{(21)} - \bar{Y}^{(11)}\right)}_{\text{Stage 2: Estimates } \delta}$$

The HODOR design



Contact*
Nicholas Larsen
nalarsen@ncsu.edu
larsenalfredo@gmail.com

Unbiased, with Minimal Variance

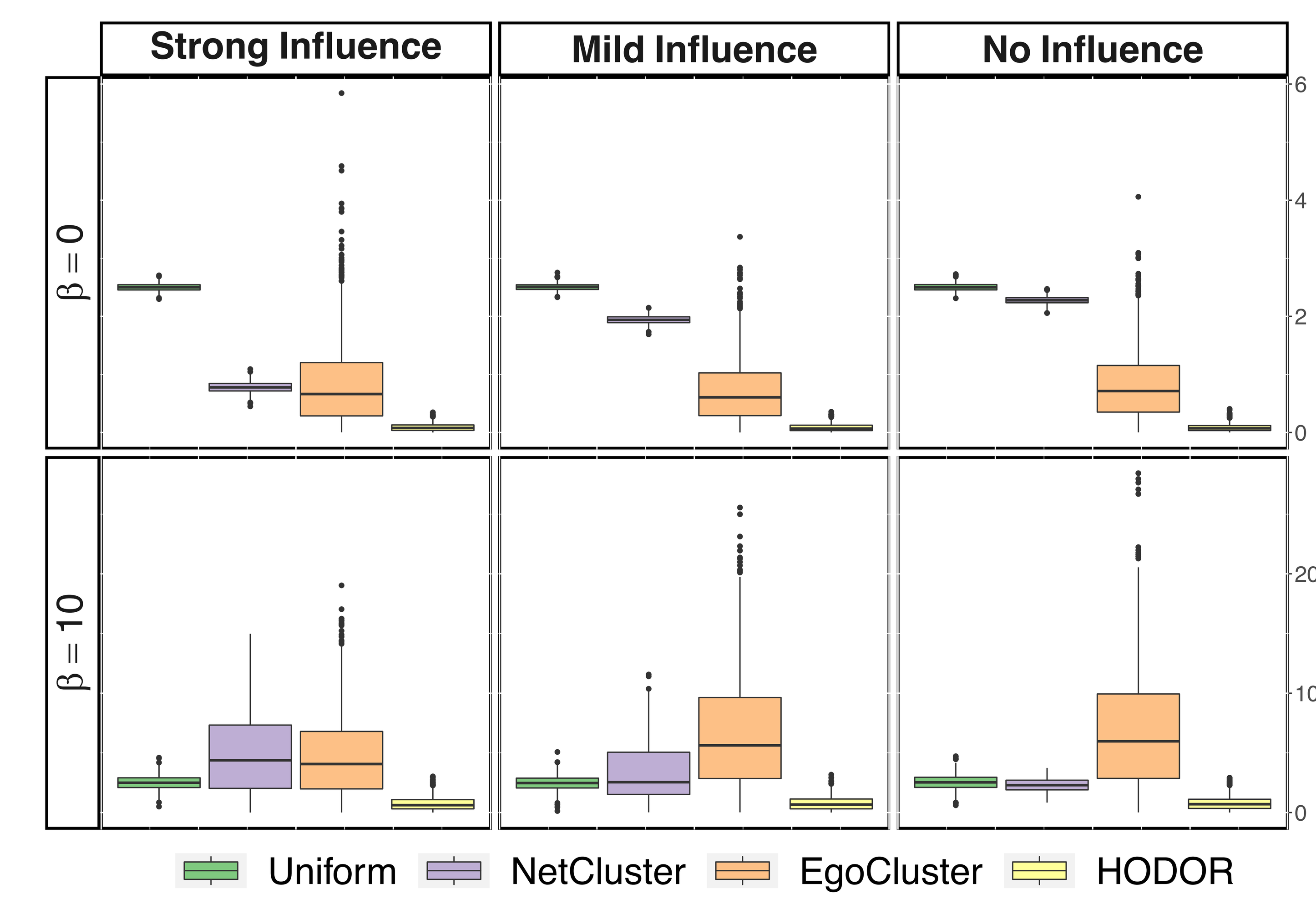
Theorem 1. *Under the given framework & using the HODOR design, our estimator has the expected value*

$$E\left[\widehat{ATE}\right] = \gamma + \delta,$$

and its variance is approximately minimized for $p_0 = 0.19$, $p_{11} = 0.06, p_{21} = 0.75$.

Simulations

HODOR achieves smallest error, regardless of whether all network information is known.



Conclusions

HODOR yields desirable results when:

- The network structure is entirely known.
- The network structure is at least partially unobserved.
- There may or may not be hidden features correlated with the response.

Unobserved features that are correlated with the response introduce bias to the NetCluster and EgoCluster designs.

Future work will replace the approximate variance expression from **Theorem 1** with an exact expression and derive tools for statistical inference using HODOR.

References

1. Saint-Jacques, Guillaume, et al. "Using ego-clusters to measure network effects at LinkedIn." *arXiv preprint arXiv:1903.08755* (2019).
2. Gui, Huan, et al. "Network a/b testing: From sampling to estimation." *Proceedings of the 24th International Conference on World Wide Web*. 2015.