Learning about Protecting Distributed Infrastructure from Behavioral Economists

Saurabh Bagchi
ECE & CS, Purdue University

Joint work with:

ECE: Shreyas Sundaram, Mustafa Abdallah
Economics: Tim Cason, Daniel Woods

Supported by NSF SaTC grant CNS-1718637 (2017-20)

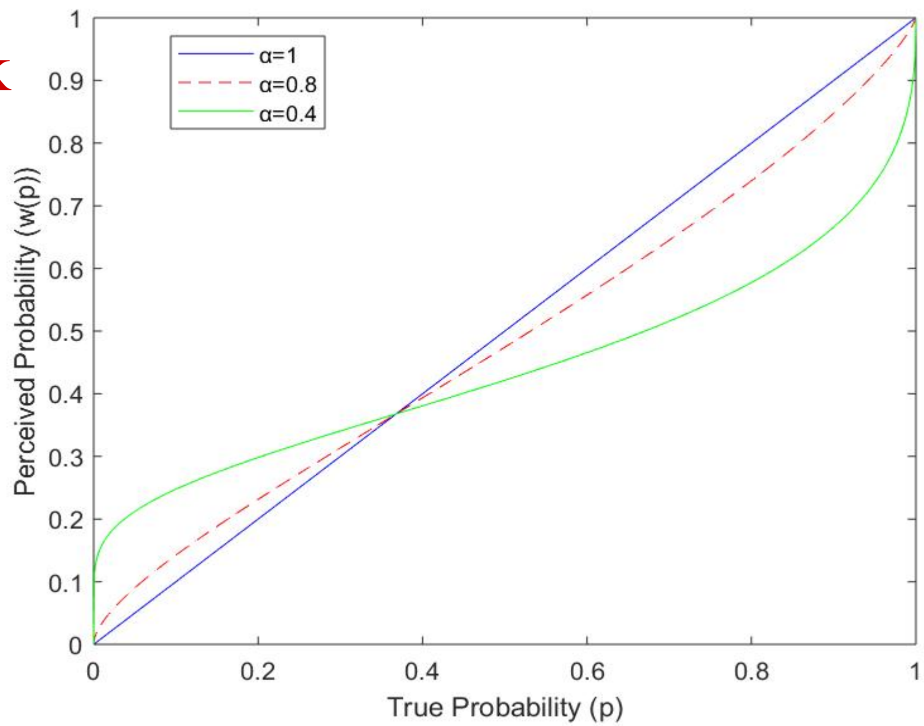
Security is Only Too Human

- Security of large-scale systems (such as the power grid, industrial plants, and communication and computer networks) depend critically on **human** decisions
- A few thousand papers on optimal decision making for protecting interconnected systems
- But relies on classical economic models of **perfectly rational** and optimal behavior for human decision-makers
- But behavioral economics shows humans are only **partly rational** and thus, consistently deviate from the above-mentioned classical models.

Behavioral Weighting Function

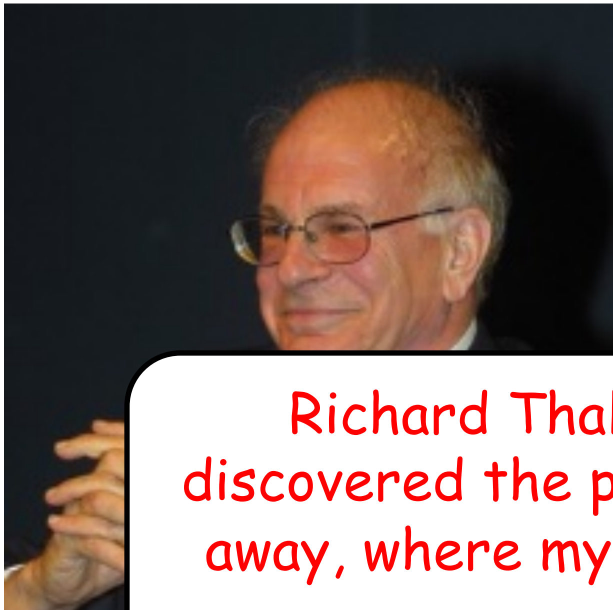
- Human perceptions of rewards and losses can differ substantially from their true values
- These perceptions can have a significant impact on the investments made to protect the systems that the individuals are managing.

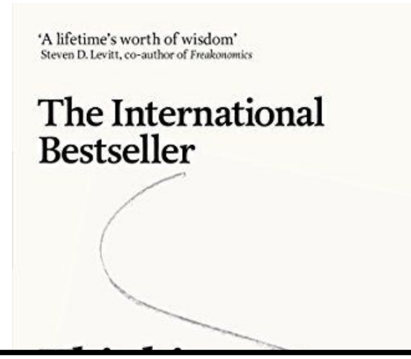
- Humans overweight low attack probabilities and underweight large attack probabilities.
- Example: Prelec [1998] weighting function:
- $w(x) = \exp(-(-\ln(x))^{\alpha})$
- where parameter $\alpha \in (0,1]$.



PURDUE UNIVERSITY

What's Nobel Got to Do With It?





Richard Thaler (2017 Economics Nobel Laureate): "I discovered the presence of human life in a place not far, far away, where my fellow economists thought it did not exist: the economy."

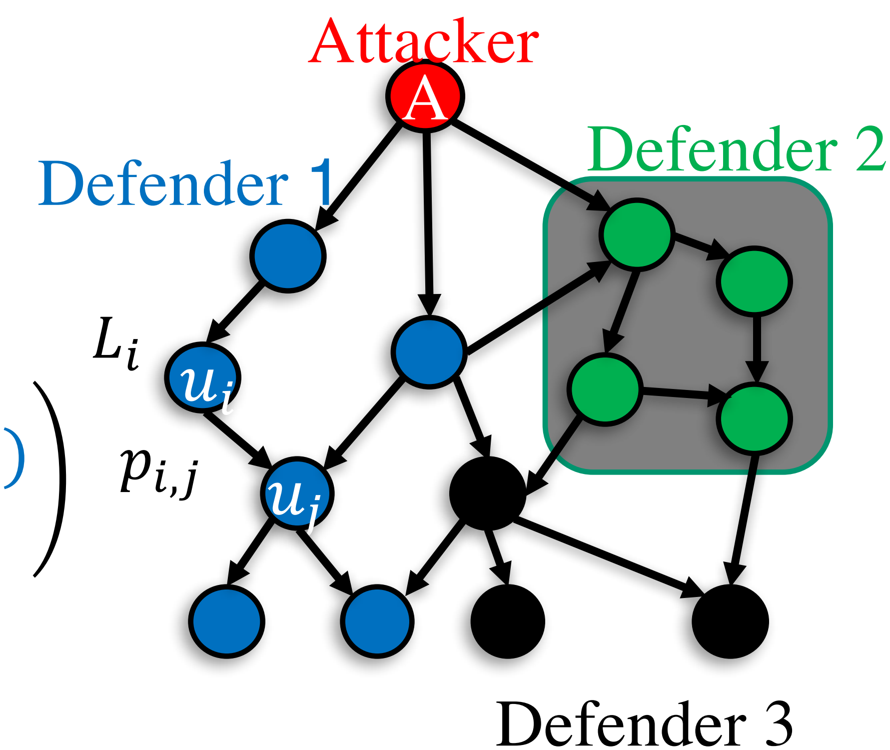
a counterpoint to expected utility theory

Our Research Direction

- **Game-theoretic framework** involving attack graph models of large-scale interdependent systems and multiple defenders
- Each **human** defender misperceives the probabilities of successful attack in the attack graph
- We characterize impacts of such misperceptions on the security investments made by each defender

  - The cost of a defender D_k is:

$$C_k(\mathrm{x}) \triangleq \sum_{u_m \in V_k} L_m \left(\max_{P \in \mathbb{P}_m} \prod_{(u_i,u_j) \in P} \boldsymbol{w}(p_{i,j}(\mathrm{x})) \right)$$

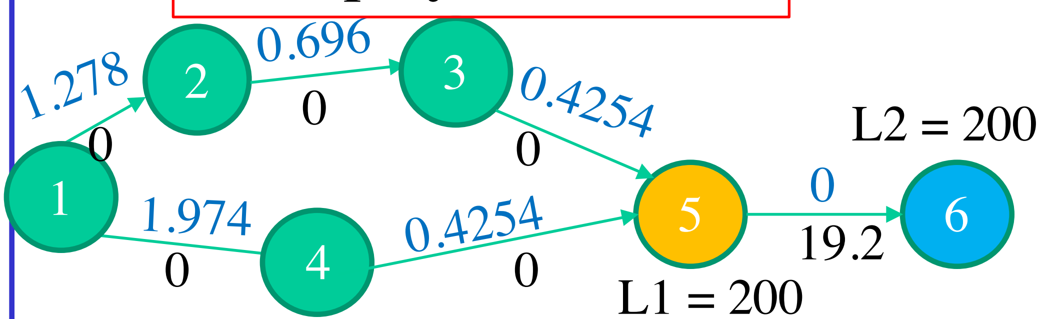


PURDUE UNIVERSITY

Initial Observations

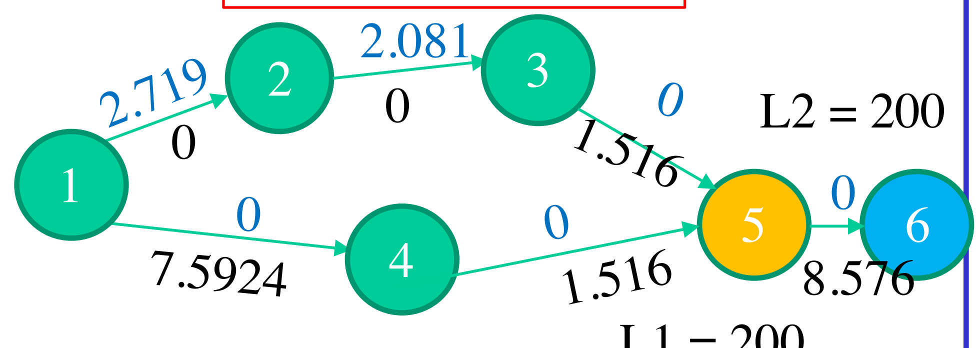
- Both games (vertex based and path based) have **Convex cost function** given a convex decreasing probability function
- Both games have a **Pure Nash Equilibrium (PNE) state**
- In each game, we can compute the best response by solving a convex optimization problem
- They have **different investment decisions** than standard security game which maximizes expected utility
- A rational player **can benefit** from a biased player

Both players rational



Overall Loss =18.1436

Player 2 biased



Overall Loss = 0.3616