Modeling Power Distribution to Heterogenous Customers in the Presence of a Strategic Adversary

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***Abstract*—Abstract goes here, especially once I get this in a better / more rigorous format. Bare bones for now.**

I. Introduction

It is trite but true that the power grid underlies most of modern civilization. Traditionally the power grid has had a few fixed producers that sell power to utilities, who in turn distribute it to their customers. Traditionally these customers have not coordinated with the utility, but simply bought whatever power they need at the prevailing price. Similarily, utilities have simply ensured that they have enough power to meet their customer's demands.

The future will be very different. More producers will enter the grid as renewables like wind and solar become more prevalent. Increased connectivity through the Smart Grid will allow consumers to be price sensitive, and put off demand during peak usage (and thus peak price) hours where possible. This will smooth the demand curve that utilities face, and make the grid more predictable.

In the smart grid, consumers will communicate their power demands and constraints to the utility, who will then schedule power dispatch to them accordingly. The crucial insight here is that some power consumption, such as running the dishwasher or charging an electric vehicle, is flexible as long as it is completed by a certain time. Other power consumption, such as running the AC in the summer is not flexible. In total though, this will give the utility more flexibility in dispatching power, and will smooth demand.

Offsetting the demand smoothing from increased consumer flexibility will be increased variation in power supply. More and more power will come from distributed and unpredictable sources: renewables such as wind and solar. These power supplies may flucuate during the day, and the level of power available from them at any given point is not knowable in advance.

This creates a coordination and scheduling problem for the utility. The utilities goal is to use all available power at any given time, constrained by the need to meet consumer's demands. If the utility faces a short fall, it has to turn to more expensive standby power sources to make up the difference. Any power that the utility cannot dispatch is wasted.

This scheduling problem is not the only difficulty facing the utility though. Information about consumer power demands and constraints as well as the amount of power being produced flows over a communications network, and it is tautological that any communications network can and will be attacked. We propose a malicious strategic adversary with strong abilities, whose goal is to destabilize the grid while remaining undetected.

TODO: Finish overview of our paper and results. Add citations. This introduction may well serve as the related works section if need be.

II. Model

A. Producer

We focus on renewable energy sources, which provide a fluctuating amount of power. Each sources produces a uniform random amount of power in a given interval. This amount of production is bounded by the minimum for the source and its maximum production capacity.

TODO: Is this the right way to go here?

B. Consumer

We model three different types of consumers, classified based on the flexibility of their demand. These follow the standard templates in literature for heterogenous consumers.

The first and most flexible class is buckets. Buckets are modeled after (... check the citation). As such, they can store power up to their maximum capacity. Buckets also consume power, and have a minimum floor that they cannot fall beneath.

The second class are batteries. Batteries have to be charged (receive a given amount of power) by a fixed end point. However, they do not have to charge continuously, and do not loose power when not being charged.

The least flexible class are bakeries. Like batteries, bakeries must receive a given amount of power, unlike batteries they must receive power continuously. Intutitively, think of baking bread. The over must remain on continuously for the bread to be properly baked (ie edible).

TODO: Give the equations, or maybe just say they are in the reference?

C. Utility

The utility's goal is to dispatch all power generated in a given time period. Each megawatt of power wasted incurs a penalty, ad does each megawatt of power that has to be used from standby sources.

TODO: Should these penalties be weighted? I'm inclined to say that standby should have a larger penalty: perhaps 2x.

III. Game

This section defines the game at a given time step. We work with both single and multi-round games in our analysis. The game is played between a strategic adversary that seeks to maximally disrupt the grid, within the constraints of his resources and the utility company whose objective is to dispatch all power at the time step.

A. Adversary

We consider three different adversary models:

Jamming The attacker can jam communication between the utility and producers / consumers. We consider scenarios where the attacker can jam 30% or 60% of communications between producers / consumers and the utility.

TODO: This is not particuarly novel, there is prior work on jamming.

njection - Load The attacker can modify the communicated demand from consumers / supply from producers. Here the attacker is constrained to a small change of less than 50%. We analyses scenarios where the attacker can modify 30% or 60% of the communicated information.

TODO: There is a lot of prior work on vanilla FDI, not novel.

dify Constraints Attacker can change the consumer's time constraints. The attacker can thereby decrease the flexibility .....

Add Constraints

The attackers optimization function is the inverse of the utilities: trying to maximize instead of minimize.

B. Utility

Utility defaults to base state for each consumer if communication fails. Conceptually, this is their demand at the same point the prior day.

Utility seeks to minimize power wastage / excess demand.

Utility can schedule the known demand of consumers in order to minimize this wastage. What scheduling strategies should the utility use, is this something we want to get into?

What is the Utilities defensive strategy: detect? If detect, can it do better than fall back to default?

IV. Experimental Results

V. Related Work

VI. Conclusions