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6.033 DP Prep Assignment

1. Introduction

New technology and pushes for environmental awareness have changed the landscape of energy production and usage. To adapt to the increasing availability of small-scale solar power, the city of Centertown, MA intends to deploy a new energy management system that supports energy sharing between residents and a more decentralized control system (p. 3). The proposed management system will be responsible for reliably providing power for residents, calculating billing, and collecting usage data for researchers and future improvements to the system.

This paper will outline the specifications for Centertown's energy management system and highlight remaining questions about the design. We will first discuss the structure and behaviors of the system. Later on, we will cover use cases, design priorities, and additional questions about the system in the following sections.

2. System Structure and Responsibilities

Centertown's electric system is structured in three hierarchical layers, each with its own required functionality. At the lowest layer, each building or apartment is equipped with its own set of smart meters, which measure and aggregate data as necessary (p. 6-7). At the next layer, the buildings in Centertown are divided into microgrids, each managed by its own microgrid controller. The microgrid controllers oversee the smart meters in their respective microgrids and communicate with the central utility to send data and receive commands (p. 8-9). Finally, at the top layer, a central utility receives data from the microgrid controllers and calculates billing for all components of the electric system. The central utility carries the majority of the system's data storage and computational power (p. 10). The central utility is also responsible for making management decisions such as prioritizing energy distribution to specific locations and purchasing power from the New England regional utility to supplement the town's electricity (p. 6, 10). Communication between layers of the system will be handled by local LTE service and internet connectivity for the central utility only (p.10).

Along with the roles of the central utility, we must also implement the following functionalities for the microgrid controllers. First, the microgrid controllers are responsible for communication between levels in the electric system, sending and receiving data and instructions. We will need to design the commands sent between the central utility and microgrid controllers. The microgrid controllers and central utility will also have to account for limited storage and network traffic when deciding to aggregate data at the cost of granularity (p. 8). In addition, the microgrid controllers must manage and record energy sharing within their microgrids. The microgrid controllers will identify and direct energy from locations with excess energy to locations that have fallen below their minimum energy levels. Finally, the microgrid controllers must be able to operate their microgrids independently in the case that the central utility is taken offline (p. 8-9).

3. Use Cases and Priorities

As mentioned in the specification, the system is expected to perform well under the following use cases: normal operation, extreme power demand, storm outages, and long-term changes (p. 11-12).

In all cases, our primary focus must be the residents of Centertown. We will prioritize the reliability and efficacy of the system in delivering power to residents and ensure accuracy of billing and energy distribution. While functionality comes before cost, it is important to minimize the cost offset to residents for system resources like additional LTE network capacity (p. 10). Under extreme power demand, we will also need to ensure that public buildings such as the hospital, fire station, and police station have priority in receiving power followed by the subsidized apartment buildings (p. 5).

In line with ensuring functionality of the system, the ability to delegate control to the microgrid controllers is essential in the case of outages, especially if the central utility goes offline. The system must be able to detect outages and respond appropriately. We will also consider ways to facilitate recovery from outages by quickly identifying the location of failure.

Our secondary priority is to collect as much data as possible from the system for long-term planning and use by researchers (p. 10). This will require balancing network and computational resources with preserving data granularity. In these cases, it may be acceptable to sacrifice speed to gain extra data as long as the functionality of the system is not compromised.

In addition, we will want to consider our impact on the environment, the scalability of our system to include new buildings, and the system's adaptability to changes in power demand. It will also be important to ensure that our management system can be readily maintained and updated by other engineers or parties in the future.

4. Additional Questions

- Where is the information for each resident's power threshold (25%, 50%, 75%) stored? Is this information read directly from the smart meters or do the microgrid controllers store them and retrieve the data themselves? How do we allow residents to set or update their power thresholds?
- How reliable is the data network? Is there an amount of transmission error to be expected from the LTE network?
- How volatile are the power fluctuations for each building's stored energy, and are there costs to constantly re-distributing power among buildings (i.e. power loss, equipment degradation)? If a building on average has 75% percent battery one day, how many times will we expect to dip slightly below 70%, below 50%?