Undergraduate Thesis Prospectus

A Solar-Powered Fleet Tracking System for Rural IoT Applications
(technical research project in Electrical and Computer Engineering)

Electric Cooperatives and Community Solar: The Democratization of Rural Electricity
(STS research project)

by

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October 31, 2019

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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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General research problem: rural revitalization

How can rural communities achieve economic and technological revitalization?

In the past 100 years, America's rural population has declined, widening an economic and social divide between rural and urban communities (Audirac, 1997). This worldwide divide has been exacerbated by technological innovations, such as electricity and the internet, that can leave rural communities disconnected from the rest of the world. Remedial strategies have included developing new agricultural practices or attracting new enterprises (Audirac, 1997). Developments in the Internet of Things and renewable energy provide an opportunity to revitalize the agricultural sector (Blair et al., 2011; Dlodo and Kalezhi, 2015).

A solar-powered fleet tracking system for rural IoT applications

How can the Internet of Things better service rural communities?

This capstone project includes four student collaborators: Nayiri Krzysztofowicz, Vivian Lin, Malcolm Miller, and Nojan Sheybani. The capstone advisor is Professor Powell of the Electrical and Computer Engineering Department.

The rise of the Internet of Things (IoT) has revolutionized the way we monitor systems. Through the use of distributed sensors and vast communication networks, the IoT provides connectivity and intelligence to our daily lives (Li et al., 2014). However, reliance on cellular or broadband networks and primary cell batteries (non-rechargeable) limit IoT applications in rural America (Da Silva et al., 2018). Low Power Wide Area Network (LPWAN) protocols such as LoRa (long range) are an emerging alternative to cellular or broadband networks. LoRa can operate independently of existing infrastructure, providing a long range, low power solution

suitable for rural deployment (Paredes-Parra et al., 2019). LoRa is conducive to solar energy harvesting, which provides reliable off-grid power without the replacement needs of a primary cell battery (Wu et al., 2017). Use of alternative network protocols and a self-powered system provides a framework for reliable IoT application in rural communities which will be applied to create a solar-powered fleet tracking system.

Similar fleet tracking systems exist in academic research and the commercial sector. Da Silva, et al. created a battery-powered tracking system using LoRa protocol, and had a high success rate of transmissions and high accuracy of GPS data using that protocol. Our system will expand on their work by integrating renewable energy for a self-powered system. Most commercial products connect to cellular networks, making them unreliable in rural areas. An example is the Samsara AG24 low-power fleet tracker. It is battery-powered by a primary cell battery, but has solar panels built-in as a backup power source. It uses a SIM card to connect to 4G LTE which increases power consumption and decreases rural reliability (Samsara, n.d.).

Our system will consist of two solar-powered roaming nodes and a central home node. The roaming nodes attach to a vehicle, and will transmit real-time GPS location data to the home node. The home node will process that data and send it over a wired connection to a personal computer which visualizes the received information on a map interface. A visual of the proposed system is shown below (fig. 1).

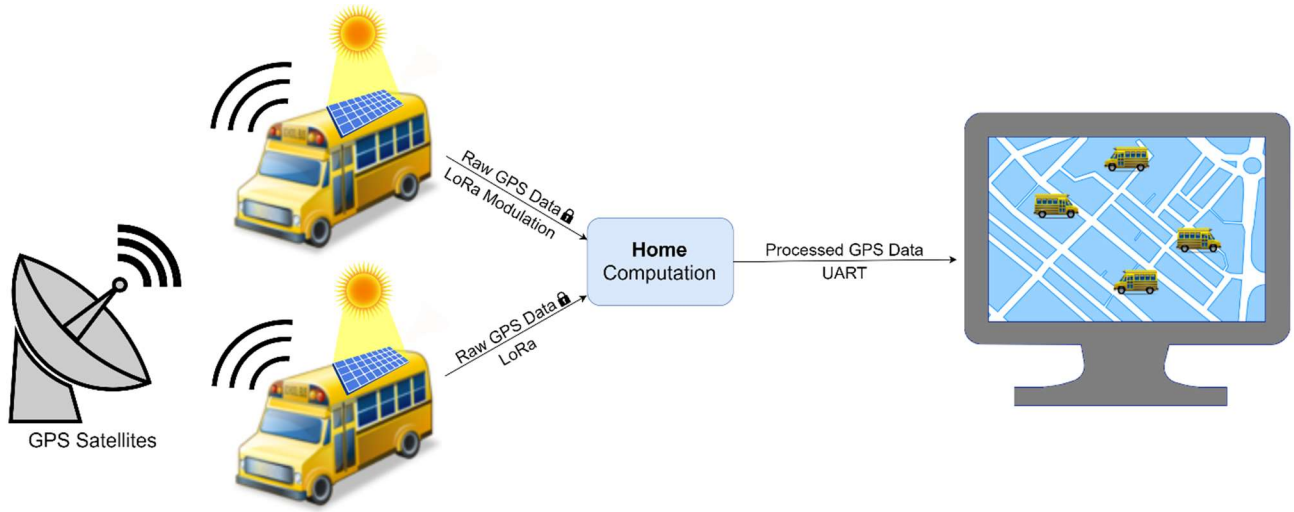

Figure 1. System Diagram of the Solar-Powered Fleet tracker (author)

The system will use LoRa protocol for secure communications, operating independently of pre-existing infrastructure. It accounts for potential security breaches by encrypting the GPS data during transmission. The custom network protocol will prevent lost or corrupted data during transmission. The home node will be powered through a wired USB connection and will use custom Python code to visualize the tracking data. The home node circuitry is an existing board developed by team members over the summer. The roaming nodes will be powered by solar panels and lithium ion batteries which provide long-term, sustainable power without the use of primary cell batteries. The team will create custom printed circuit boards for the roaming nodes. Each will consist of a power subsystem and a communications subsystem. The expected outcome of the project is a standalone, scalable network of devices tracking a fleet of vehicles.

Electric cooperatives and community solar: the democratization of rural electricity

How do electric cooperatives promote energy democracy in rural America?

Many organizations cite electrification of the United States as the most impactful achievement of the 20th century (Cooper, 2008; USDA, 2005). FDR's Rural Electrification Administration of 1935 (REA) was a turning point for rural communities, providing electricity through the creation of rural electric cooperatives (Nicholson, 1936). The federal government presented REA as an opportunity to increase rural standard of living and revive farm economies (Campbell, 2000). Similarly, a politician from Mississippi said that "if properly carried out, [REA] will result in the greatest back-to-the farm movement of all times" (Rankin, 1935). However, beneath this manifest function of rural revival was a latent function to create a new customer base for electrical products and to boost the Depression-era economy through an emphasis on cheap electrical rates (USDA, 1998). REA produced a system that emphasized energy consumption, exacerbated economic and racial divides, and relied on coal-fired generation (English, 1997; Harrison, 2016; Spinak, 2014). Kentuckians For the Commonwealth (KFTC) describes the result as a system of "old power" based on capitalism, consumerism, and political control[1] (KFTC, 2019).

Electric cooperatives are part of a larger period of energy flux, where "old power" technologies are retiring and "new power" is taking their place. KFTC describes "new power" as "a more authentic democracy, a just and sustainable economy, and a clean energy future" (KFTC, n.d.). Energy democracy, referring to a decentralization of electric power and increased community control over energy resources, is a key component of new power and is often associated with distributed renewable energy systems such as community solar (Hoffman and

[1] An in-depth history of the REA, electric cooperatives, and energy policy is necessary to truly describe "old power" and has been omitted due to the limited word count. It will be described in detail in the final research paper.

High-Pippert, 2015). Electric cooperatives are in a unique position to advocate for rural energy democracy, and are a part of a large network of national and local participants involved in energy policy and decision making.

Researchers have examined old power and opportunities for electric cooperatives in energy democracy. Nye (1990) contends that rural electrification is an urban colonization of rural markets, finding that corporate and government visions for electrification both sought to "integrate farmers into the national market." Spinak (2014) found that cooperatives can promote energy democracy by transitioning from consumer to producer, stating "it is only when energy policy becomes tied to possibilities for local development…that electric co-ops have become meaningful democratic forums." Hoffman and High-Pippert (2015) examined institutional and local approaches to community solar projects, arguing that many projects fail when they lose sight of participants' needs and of the importance of civic engagement.

Two levels of participants influence power in rural America: national and local. National participants include the US Department of Agriculture (USDA), the National Rural Electric Cooperative Association (NRECA), and the EPA. Local participants include rural electric cooperatives, their members, and local advocacy groups.

Although electric cooperatives have been called the "ultimate in self-reliance" by NRECA, they are still tied to the organizations that created them (USDA, 2005). REA is now administered by USDA Rural Utilities Service (RUS) which continues to support electric cooperatives through loans and funding. Recent programs include the Electric Loans Program and the Rural Energy Savings Program (USDA, n.d.). In 1995, NRECA called the USDA "the primary leader to many rural electric systems," and in 2000, the RUS Administrator said that "it is imperative that the federal government be actively involved in providing a funding network of

support services" (Campbell, 2000; English, 1997). These statements highlight the imbalance of power between the electric cooperatives and the institutions that support them.

Energy democracy represents the value of community control. Thus, many national participants appeal to local participants' values to promote their agendas. NRECA and USDA both outwardly support renewable energy and distributed generation. USDA uses words such as "sustainable" or "modern" to describe its electric power loans, which can be used to develop renewables (USDA, n.d.). NRECA's published mission is to "provide a path toward a cleaner, more sustainable future," through distributed energy systems, community solar, and battery storage (NRECA, 2019). In 2014, they launched the SUNDA program to demonstrate solar energy potential in the rural U.S. It is described as a "solar revolution" in an NRECA report (NRECA, 2018b). However, in a 2018 document presented to the EPA, NRECA admits that while it supports renewables, it has "significant interests in coal-fired generation," primarily due to EPA support for coal in the 1970s (NRECA, 2018a). NRECA has fought against EPA regulations supporting clean energy, supporting the repeal of PURPA and the Clean Power Plan (English, 1997; NRECA, 2018a).

Electric cooperatives lead the nation in offering community solar programs, responding to member demand for sustainable energy and increasing their energy democracy (NRECA, 2018b). In 2018, the Central Virginia Electric Cooperative (CVEC) launched a 10 MW Solar Share program, the largest in the state of Virginia. This program has allowed CVEC to "fulfill their mission in offering clean, renewable energy" (CVEC, n.d.). Similar statements have been echoed by electric cooperatives across the country. However, many electric cooperatives face challenges. Farrell et al. (2016) found that long-term coal contracts and lack of member participation are the biggest obstacles to renewable energy integration. Lack of member

participation could be due to a reactance against perceived threats to members' energy freedom as well as their local economy and traditions. Many beliefs are motivated by political polarization and fear of damaging the coal industry. Olson-Hazboun (2018) found that in coal-dependent areas many people believe that "renewable energy [is] simply one of the mechanisms by which liberals [are] hurting fossil fuels communities." Local advocacy groups such as Kentuckians for the Commonwealth (KFTC) work to increase co-op member participation and interest in distributed energy systems. KFTC members believe that their message about energy democracy will catch on through a social norms campaign. "I think these ideas are going to take hold and spread as more people see their friends and neighbors saving energy, using renewables, and saving money in the long term" says KFTC member after presenting to a local co-op member meeting (Pennington, 2012). Local participants often have conflicting views on energy democracy, and national pressure to reduce reliance on coal exacerbates regional differences (Olson-Hazboun, 2018).

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