Imperial College London

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Yuchen Wang
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Abstract

In many developing countries the electricity grid network is underdeveloped, causing low levels of rural electrification. However, electricity access in these rural communities are not non-existent. There are a number isolated and independent electricity generators owned by individuals, NGOs and local government institutions. This project explores the feasibility of a Decentralised Community Energy System which utilises these isolated sources of electricity to create a community micro grid. It is planned to conduct the feasibility study with the help of a simulation to be developed using Presage2 and Java. This report outlines the deliverables, planning process, background research, and the design and implementation of the simulation model.

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Introduction 1

In many areas of rural developing countries, there are often no wide-spread access to a continuous and reliable electricity supply such provided by the country's electricity grid.[?] However there exists many isolated sources of electricity generation such as solar panels and standalone diesel generators utilised by relatively wealthy households, shops and buildings belonging to large organisations.

The aim of this project is to explore the idea of using a holonic institution to model a Decentralised Community Energy System which bring together the existing decentralised generation infrastructure to provide an affordable source of reliable electricity for users in rural communities.

Over the course of this project, a multi-agent simulation model was built using Presage2 with individual households and businesses modelled agents. The agents can be grouped together to form communities such as villages, which in turn can be grouped together to form a larger entity such as a district or a province.

With humans being social creatures who are likely to band together to form communities, the structure of the decentralised energy system model will be designed in a similar way with holonics. The structure of how the simulation is designed is based on the design of holonic systems. In the case of this project, the simulation will be to distribute fairly electrical power between interrelated agents which are in turn composed of interrelated subagents recursively, until reaching lowest level of subagents (households and businesses).

To allow the model to be realistic, candidate rural communities with no access to a source of reliable electricity will be identified using data and research. Additional data on usage habits and potential generation profiles of generators in the candidate areas will be obtained through research to produce a simulation model that is accurate and relevant.

Include:

- Design Choices: Holonics, design of objectives
- difficulties and how they were designed:

  Out of order parallel execution

  Presage

  One action per time step
- Discovery or invetion of something novel?
- What did you learn:

  Java, Presage, Software design

This report outlines the design, implementation and testing of a holonic multiagent simulation of a decentralised energy system.

Background 2

2.1 Electricity as a Common Pool Resource

A Common Pool Resource is a depletable resource which can be utilised by a group of people, characterised by a reduction in the availability of this resource as individuals withdraw or utilise this resource.[?] Electricity can be a Common Pool Resource if there exists a finite amount of electricity generation capacity. As users connect demand appliances to the generators, the availability of electricity supply for additional demand diminishes.

In developing communities with significant generation from renewable sources such as wind and solar, the availability of power is subject to variation between periods in time. This inherent volatility in the amount of available resource could increase the likelihood of selfish actions of by individuals in the community.

Common Property Regimes can be formed to maintain the Common Pool Resources by controlling the access to the resource.

2.2 Decentralised Community Energy Systems as a Holonic System

A holonic system (or holarchy) is a system which is composed of interrelated subsystems or institution, each of which are in turn composed of sub-subsystems or institution and so on, recursively until reaching a lowest level of "elementary" subsystems. Each system, sub-system or institution has a well-defined set of goals or objectives which is achieved through enforcing a set of rules on its members (subsystems, sub-institutions and elementary entities). It is this type of Common Property Regime that will be explored in this project to maintain the Common Pool Resource that is electricity.

In the context of a rural Decentralised Community Energy system, a network between households, communities and even villages to pool and share electricity as a common pool resource can be modelled as a holonic system. The holonic system in this case would be composed of communities such as Districts, Provinces, Sectors which are composed of sub-communities such as Towns and Villages. The sub-communities would be composed of many "elementary" such as households, businesses and other points of connection for electricity. Each community or institution has the goal of fairly allocating electricity to all members. This goal would be achieved with the assumption that they are provided with the necessary infrastructure and powers for enforcing quotas and contribute to a common pool of electricity.

2.3 Rural Communities in Rwanda

With an estimated 25% rural electrification rate in 2009,[?] rural Africa is one obvious candidate for simulation scenarios. Vast amounts of rural communities remain un-electrified. For a realistic simulation scenario, knowledge of existing infrastructure in place will need to be obtained. With many areas within many countries in Africa, Rwanda in particular has been identified as a good potential simulation scenario to research. Data is difficult to source for rural communities in developing countries, however in the case of Rwanda, some data can be easily from the student society e.quinox. e.quinox is a student-led society which aims to find a scalable solution for rural electrification who mainly operate in Rwanda.[?] The subsections below outline some of the ways remote rural communities are able to access electricity in Rwanda.

2.3.1 Electricity Generation

One of the solutions currently being implemented by e.quinox is the "Energy Kisok" model.[?] The "Energy Kiosk" model features an Energy Kiosk - a building where the generation, storage and distribution of electricity takes place. In e.quinox operated kiosks, electricity is generated from renewable sources. Traditionally, this has been with solar panels. However, hydro-electric generation has been demonstrated to be feasible with the recent construction of a "Hydro Kiosk" at Rugaragara Falls in Southern Rwanda.

2.3.2 Storage and Distribution

Within each kiosk, electricity that is generated is stored in storage batteries placed in the kiosks. The storage batteries regulate power output and allows access to electricity in the kiosk even during periods of no electricity generation.

2.3.2.1 Battery Box

In the absence of any electricity distribution infrastructure, e.quinox has traditionally provided a number of portable batteries for the purpose of electricity distribution. An example of the portable batteries can be seen in Figure 2.1.

Consumers from local community pay to hire the battery boxes under one of two payment schemes: pay-per-recharge and pay-per-month.[?] The biggest difference between the two schemes are that users can recharge as often as they would like with pay-per-month. Both payment schemes involve the recharge of the boxes at the energy kiosk when they are depleted of energy.

A potential use case of this project can be the simulation of charging of battery boxes at an energy kiosk. This could alleviate congestion and improve asset utilisation of the existing distribution systems by reducing the turn-around time of battery boxes for customers.

2.3.2.2 Micro Grid

With the recent completion of a hydro-electric kiosk. e.quinox for the first time has a kiosk with access to an always-on generator. With a limited number of battery

FIGURE 2.1: First Generation e.quinox Battery Boxes deployed at Rugaragara Falls Kiosk

boxes in circulation and a constant generation available during the off-peak hours, there is excess capacity for electricity generation.

To improve utilisation of the generator in the kiosk, e.quinox has recently started conducting a feasibility study into constructing a transmission line and a distribution network which will serve a village near the kiosk with a view to make the most of the electricity generated.

Preliminary surveys conducted in the nearest village to the kiosk indicates the demand could exceed the amount of excess power generated by the kiosk.

The result of this project can be used in conjunction with e.quinox to conduct the feasibility study of implementing the Micro-Grid. Should a trading platform for energy also be built, the Micro-Grid could serve as a test-bed for this new system.

2.3.2.3 Standalone Solution

The Standalone Solution is an independent electrification solution which was recently developed by e.quinox for customers who live far from energy kiosks.

The Stand-alone solution consists of a pay-as-you-go solar electricity generation and storage kit, known as the Izuba.Box.[?] With the Izuba.Box, customers no longer have to travel regularly back to the Energy Kiosk for electricity. Solar panels are installed on the customerâĂŹs roof, and is connected to a sealed box which contains a large battery box. The attached large battery box allows a regulated power output and access to electricity during dark hours.

With the customers not returning to Energy Kiosks, the battery boxes are not hired out like the battery boxes are. The high capital costs of the independent solar system is spread over typically a two year rent-to-own payment plan using a mobile payment system.

It is hoped that the Standalone Solution and additional generation from the Energy Kiosk can be complemented the battery boxes in circulation to provide a continuous access to electricity to all households in the village.

Figure 2.2: First Generation Izuba.Box deplyed in Minazi, Northern Rwanda

2.3.2.4 In the context of the Project

In developing countries such as Rwanda, poor communities with no access to grid electricity are often in isolated locations. In these areas, fuel for generators are often difficult to obtain. Other available sources of electricity such as solar and wind power are highly dependent other variables such as weather. It is also highly unlikely that they will have access to redundancies to ensure continual access much like the electricity we receive from the national distribution and transmission network in the UK. It is therefore beneficial for systems such as the one we are modelling as it has lower barriers to entry than access to

Requirements 3

It is therefore required that the simulation platform will have the following features:

- Multiple Forms of Generation: Renewable and Non-renewable generators which can operate continuously or discontinuously
- Realistic Generator Models: Programmable variable generation power output to simulate wind and solar power
- Multiple demand centres: the simulation will be of one or more communities operating with a number of households/businesses requiring electricity
- Self organising by the system to appropriate the available power fairly to all users

As this is a simulation to be implemented in Presage2, there are no specific requirements which must be adhered to with regards to speed, portability and performance.

The simulation is to be developed using Presage2. It is hoped that a network of Decentralised Community Energy Systems can be simulated, and a working trading system can also be developed for the trading of limited available energy within communities towards the end of the project time frame.

Planning 4

Following a number of supervisor meetings with Dr Pitt, a number of work items have been identified. A Gantt Chart was created to facilitate the planning and tracking of the project progress. A copy of the current Gantt Chart can be seen in Figure 4.1. The Gantt Chart was a continuous working document which will be update as the project progresses. Tasks were added as new ideas for the project became available.

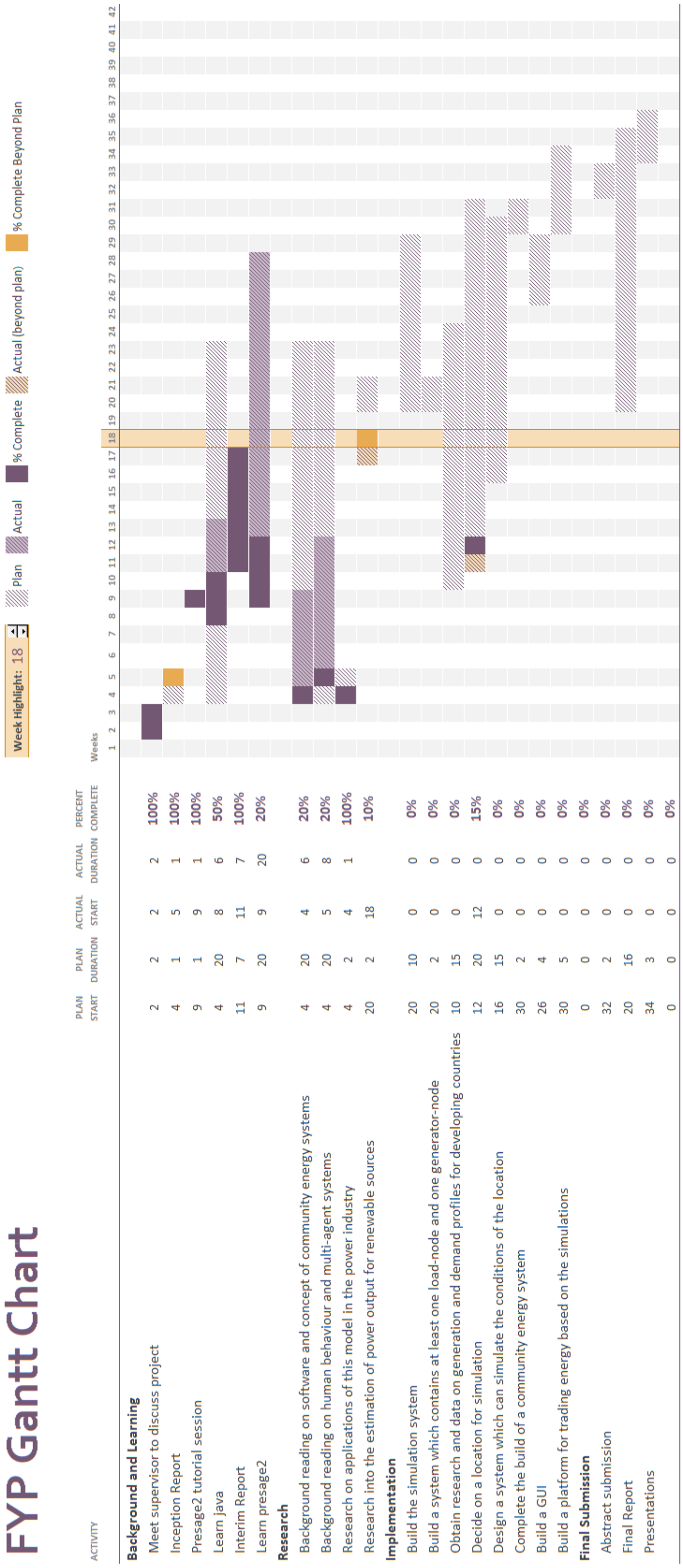

FIGURE 4.1: Up to date Gantt chart

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13 A Chapter of Examples

13.1 A Table

Feature	Misuse-based	Anomaly-based
Modeled activity:	Malicious	Normal
Detection method:	Matching	Deviation
Threats detected:	Known	Any
False negatives:	High	Low
False positives:	Low	High
Maintenance cost:	High	Low
Attack desc.:	Accurate	Absent
System design:	Easy	Difficult

Table 13.1: Duality between misuse- and anomaly-based intrusion detection techniques. Note that, an anomaly-based IDS can detect “Any” threat, under the assumption that an attack always generates a deviation in the modeled activity.

13.2 Code

```
/* ... */ cd['<'] = {0.1, 0.11} cd['a'] = {0.01, 0.2} cd['b'] =
{0.13, 0.23} /* ... */

b = decode(arg3_value);

if ( !(cd['c'][0] < count('c', b) < cd['c'][1]) ||\
     !(cd['<'][0] < count('<', b) < cd['<'][1]) ||\
     ... || ...)  fire_alert("Anomalous content detected!");
/* ... */
```

13.3 A Sideways Table

Approach	Time	Header	Payload	Stochastic	Determ.	Clustering
brea		•				•
a		•	•	•		
b		•		•	•	
c			•			•
d	•		•		•	
e		•	•			•
f			•	•		
g		•	•			•
h		•	•			•
i			•	•		

Table 13.2: Taxonomy of the selected state of the art approaches for network-based anomaly detection.

13.4 A Figure

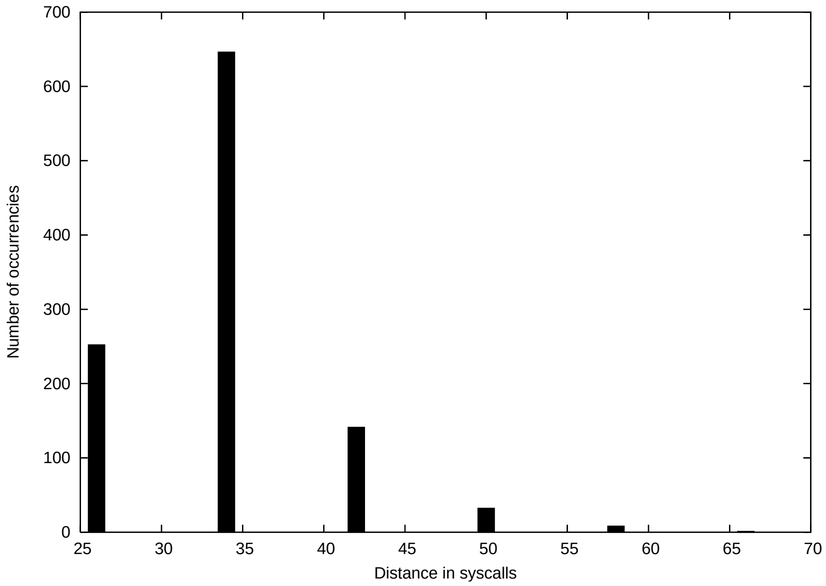

FIGURE 13.1: `telnetd`: distribution of the number of other system calls among two `execve` system calls (i.e., distance between two consecutive `execve`).

13.5 Bulleted List

- O =“Intrusion”, $\neg O$ =“Non-intrusion”;
- A =“Alert reported”, $\neg A$ =“No alert reported”.

13.6 Numbered List

1. O =“Intrusion”, $\neg O$ =“Non-intrusion”;
2. A =“Alert reported”, $\neg A$ =“No alert reported”.

13.7 A Description

Time refers to the use of *timestamp* information, extracted from network packets, to model normal packets. For example, normal packets may be modeled by their minimum and maximum inter-arrival time.

Header means that the *Trasmission Control Protocol* (TCP) header is decoded and the fields are modeled. For example, normal packets may be modeled by the observed ports range.

Payload refers to the use of the payload, either at *Internet Protocol* (IP) or TCP layer. For example, normal packets may be modeled by the most frequent byte in the observed payloads.

Stochastic means that stochastic techniques are exploited to create models. For example, the model of normal packets may be constructed by estimating the sample mean and variance of certain features (e.g., port number, content length).

Deterministic means that certain features are modeled following a deterministic approach. For example, normal packets may be only those containing a specified set of values for the *Time To Live* (TTL) field.

Clustering refers to the use of clustering (and subsequent classification) techniques. For instance, payload byte vectors may be compressed using a *Self Organizing Map* (SOM) where class of different packets will stimulate neighbor nodes.

13.8 An Equation

$$d_a(i,j) := \begin{cases} K_a + \alpha_a \delta_a(i,j) & \text{if the elements are different} \\ 0 & \text{otherwise} \end{cases} \tag{13.1}$$

13.9 A Theorem, Proposition & Proof

Theorem 13.9.1 $a^2 + b^2 = c^2$

Proposition 13.9.2 $3 + 3 = 6$

Proof 13.9.1 *For any finite set* $\{p_1, p_2, ..., p_n\}$ *of primes, consider* $m = p_1 p_2 ... p_n + 1$*. If* m *is prime it is not in the set since* $m > p_i$ *for all* i*. If* m *is not prime it has a prime divisor* p*. If* p *is one of the* p_i *then* p *is a divisor of* $p_1 p_2 ... p_n$ *and hence is a divisor of* $(m - p_1 p_2 ... p_n) = 1$*, which is impossible; so* p *is not in the set. Hence a finite set* $\{p_1, p_2, ..., p_n\}$ *cannot be the collection of all primes.*

13.10 Definition

Definition 13.10.1 (Anomaly-based IDS) *An* anomaly-based IDS *is a type of IDS that generate alerts* $\mathbb{A}$ *by relying on normal activity profiles.*

13.11 A Remark

Remark 1 *Although the network stack implementation may vary from system to system (e.g.,* Windows *and* Cisco *platforms have different implementation of TCP).*

13.12 An Example

Example 13.12.1 (Misuse *vs.* Anomaly) *A misuse-based system M and an anomaly-based system A process the same log containing a full dump of the system calls invoked by the kernel of an audited machine. Log entries are in the form:*

```
<function_name>(<arg1_value>, <arg2_value>, ...)
```

13.13 Note

Note 13.13.1 (Inspection layer) *Although the network stack implementation may vary from system to system (e.g.,* Windows *and* Cisco *platforms have different implementation of TCP), it is important to underline that the notion of IP, TCP, HTTP* packet *is well defined in a system-agnostic way, while the notion of* operating system activity *is rather vague and by no means standardized.*

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