# Its Different: Hitchikers Tryst with Energy Consumption Patterns in India

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## Abstract

This paper provides a sample of a LaTeX document for ACM Sensys. It complements the document *Author's (Alternate) Guide to Preparing ACM SIG Proceedings Using LaTeX2ε and BibTeX*. This source file has been written with the intention of being compiled under LaTeX2ε and BibTeX.

To make best use of this sample document, run it through `pdflatex` and `bibtex` to directly produce a pdf document.

## Categories and Subject Descriptors

H.4 [**Information Systems Applications**]: Miscellaneous; D.2.8 [**Software Engineering**]: Metrics—*complexity measures, performance measures*

## General Terms

Delphi theory

*Keywords*

ACM proceedings, LaTeX, text tagging

## 1 Introduction+Related Work

- Why buildings must be targeted for energy [7]
- Importance of feedback [5]
- Why we need deployments
- Deployments- Residential, Office [1, 3]
- Previous such residential deployments, some of which were presented in Buildsys itself [9, 2, 6]
- Some applications-NILM[8, 4], Fixture Finder [10]
- Specific learnings from our deployment, some of them complement the ones given earlier [9]
  - Glowing LED in night
  - Deployments should be transparent
  - Noisy server owing to dust (specific to developing countries)
  - Electricity failure- as a consequence all systems should be capable to restart upon resumption of electricity
  - Unreliable internet -Forcing to use Sense-Store-Upload paradigm
  - Normalization -Voltage fluctuation, different measurement by different instruments

Also deployment was maintained as an open source project. Shows how we faced issues and tackled them. Also contains metadata log provided by the end user.

## 2 Deployment Overview

Over the past year, we have deployed sensors across 22 homes. While 20 of these homes have been instrumented only with smart electricity meters, 2 homes have been extensively instrumented with upto 32 sensors measuring electricity, water and ambient parameter. Figure 1 shows the deployment in a 3 storey home where 32 sensors, 5 single board computers and 3 routers were used.

### 2.1 Sensing Infrastructure

For our sensing, we took a "leave no stone unturned" approach, where we chose to monitor as many physical parameters (such as ambient conditions, electricity usage, water usage) and non-physical parameters(such as network strength etc.). However, it must be noted, that we chose to deploy sensors in a way that home users can continue their regular routine without getting affected. We describe the various sensors to monitor electricity, water and ambient conditions below:

**Electricity monitoring:** A typical home electricity setup involves a meter which is installed by utility companies and measures overall electricity usage. Further electric cabling is divided into various Miniature Circuit Breakers (MCB's) which control separate circuits. Typical installations involve putting separate MCB's for heavier loads such as air conditioners and clubbing various lights, fans and other smaller loads into separate MCB. Further each individual appliance is controlled via a switch. There are two types of appliances- i) plug loads like refrigerator and electric iron, which need to be physically "plugged" into the sockets; ii) loads like lights and fans, which do not need to be "plugged" in by the user. We highlight the above described home electricity distribution in Figure 1. We have 3 different resolutions at which electricity can be monitored:



*SenSys'13*, November 11–15, 2013, Rome, Italy.

1. **Meter level:** We use Schneider Electric EM6400[1] smart meter to instrument the main power supply. This meter provides
2. **Circuit level:**
3. **Appliance level:**

## 2.2 Communication and Computation Infrastructure

Following computation resources (SBC/Servers were used)

- X RPi
- Plug Computers
- Main server

Following sensors were used.

- EM6400 smart meter: We used pyModbus to sample at 1 Hz. Gives 40 parameters including reactive power. Reactive power can greatly help in improving NILM accuracy [8].
- Appliance level meters: jPlug and Current Cost. jPlug gives data at 1 Hz and gives 10 parameters including reactive power. Current cost was needed for one appliance- electric motor.
- CT monitoring: Custom hardware based on XYZ.
- Multisensors: Measure motion (based on polling), light and temperature
- Water meter: 10 litre events.
- Android phones measuring x, y, z using FunF Journal[2]

Apart from this following soft-sensor streams were collected.

- Network statistics
- CPU, Memory usage for all computing resources. This was to serve as preventive measure.
- Weather streams

# 3 Learning

In this section we discuss the learning from previous work in similar domains and present unique aspects which came up in our deployment.

- Homes are not power panacea. We have a very special case of electricity failure. Add figure for electricity number of hours failure, failure by n'th hour, hist of failure hours
- Homes have poor connectivity. This forced us to develop a different paradigm which we call Sense-Store-Transfer. This is shown in Figure 4
- Homes are hazardous environments
  - Multi failed when put on inverter point
  - Node in one room will always fail
  - Wire snag and how it led to data loss of node 4

[1] Toput

[2] http://www.funf.org/journal.html

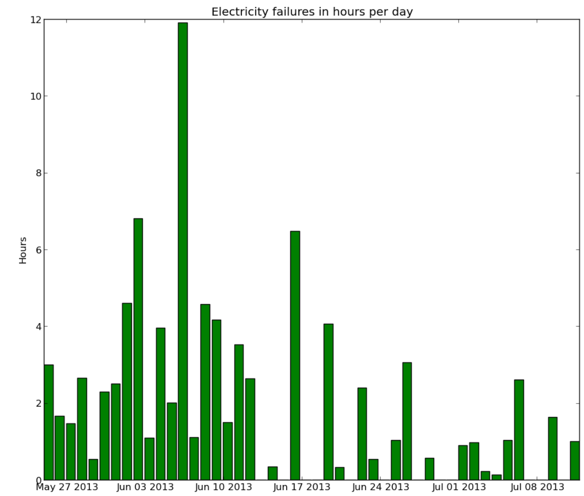



Figure 3: Electricity failure in hours

- Homes are remote environments: We had to raise 60 new issues on Github. We first did deployment in researchers home which had full access to all nodes. We also provided alerting mechanisms.
- User participation Even at researchers home, had asked the researcher to take notes. But even his engagement was not 100 %.
- Aesthetics matter
  - LED in night Figure 5
  - Noise- Noisy SMPS due to dust. Unique to our setting. Figure from FunF showing sound level before and after cleaning.
- Simplify the architecture We used Load-Store-Forward. Describe this in more detail and relate to earlier n/w connectivity. Also when number of systems is so large, simple CSV uploading is the best mechanism.

  Wherever possible use Ethernet with repeaters. Also, RPi are known to have problems with WiFi.
- Importance of meta data and calibration Figure showing power consumption of ref. after repair Figure showing different measurements for same appliance Figure showing voltage fluctuations
- Provision for more sensors than actual number required. x jplug, y multisensor failed due to ..
- Non availability of sensors in local markets

# 4 Case Studies

In this section we present some case studies from the data collected in this deployment.

## 4.1 Correlating Events and Activity Detection

In this section we show how multi-modal data can be used for activity recognition. Following plots show the same.

Table 1: Deployment

| Sensor name | Sensor type | Sampling frequency (Hz) | Resolution | Quantity | Communication | |
|---|---|---|---|---|---|---|
| EM6400 | Electric Meter | 1 | Home | 1 | RS 485, WiFi | Vo |
| Analog | Water Meter | 5 | Main supply and tank | 2 | | |
| Homeseer HSM-100 | Ambient multisensors | 1 (for light, temperature) and polling for PIR | Room | 6 | ZWave | Lig |
| Android phones | Ambient multisensors | check from funf | Room | 5 | Manual | |
| Prototype CT | Current Transformers | 20 | MCB | 8 | WiFi | |
| jPlug | Appliance electric meter | 1 | Appliance | 9 | WiFi | |
| Current Cost | Appliance CT | 0.1 | Appliance | 1 | Proprietary | |

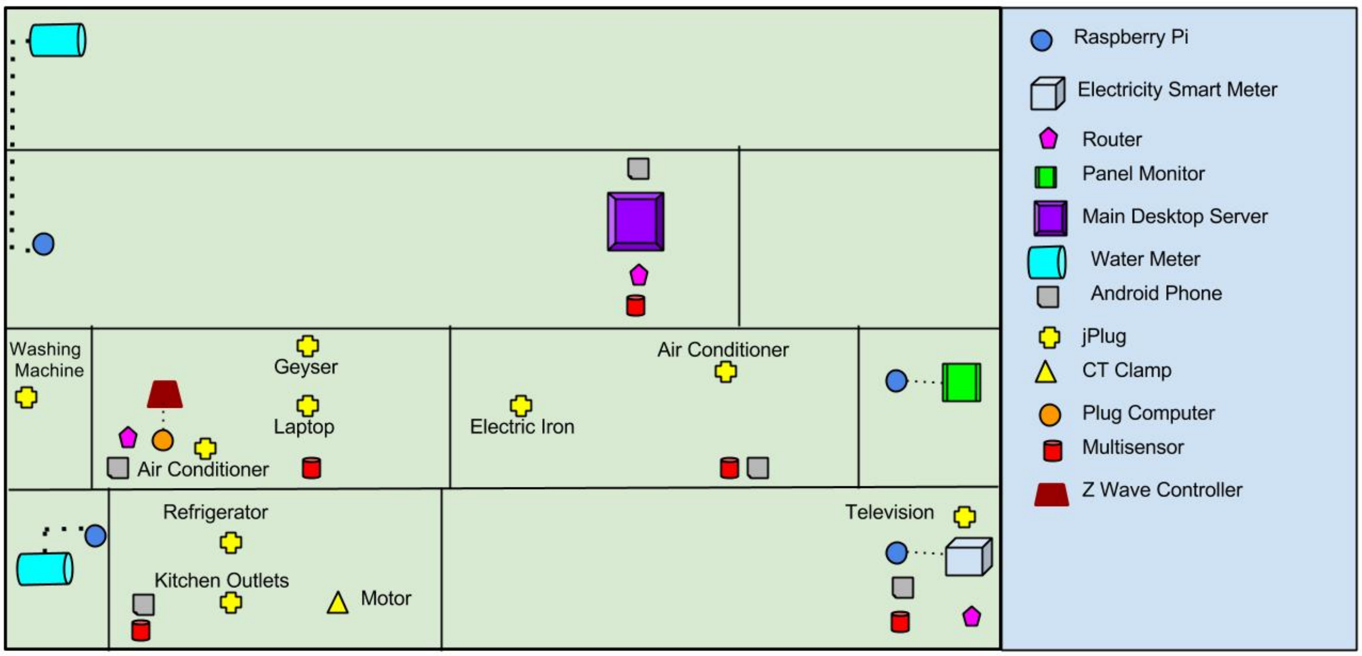
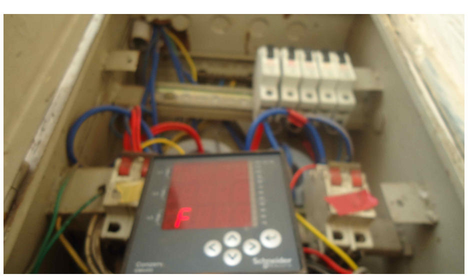
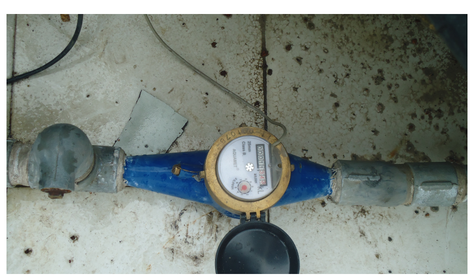



Figure 1: Schematic showing overall home deployment



(a) EM6400 Smart Meter



(b) Water Meter

Figure 2: Deployment Pictures

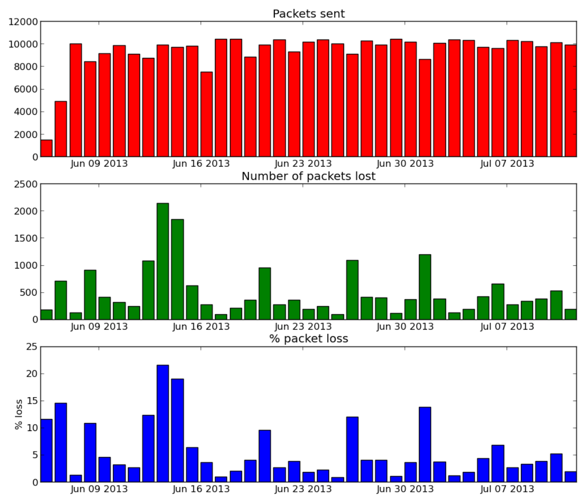



Figure 4: Overall packet drop while accessing internet

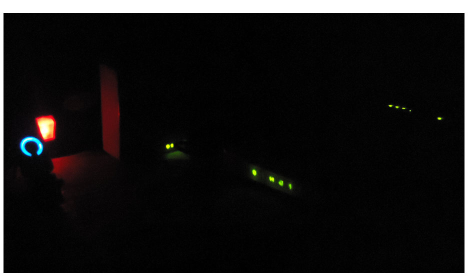


Figure 5: LED glowing in the night

## 4.2 Water-Energy Nexus

### 4.2.1 *Water Filter*

In this section we find out the effective cost of 1 litre of water. RO is known to waste a lot of water. From the water meter we observe the amount of water consumed to fill 1 litre of water. We also see the corresponding power draw of the RO. Thus, we can see that water has energy embedded in it.

### 4.2.2 *Electric Motor*

Another unique aspect of our setting is the use of electric motor to pump water. Figure showing 1 litre events before motor was turned on and figure showing 1 litre events after motor is turned on. Figure showing power consumption incurred by the use of motor.

## 4.3 Energy conscious habits

Figure showing how i turn the AC at 16 degrees and turn it off before going to sleep.

Running the ref. in least cool cooling mode and the impact it has.

## 4.4 NILM

Will be tough to do in timeframe.

To highlight any thing or add new stuff write like this in red

This is my comment. I would also do ... and put this image and put this table and so on and so forth

# 5 Conclusions and Future Work

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