Individual Appliance Monitoring System - Design Details

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SYSTEM OVERVIEW

The Individual Appliance Monitoring System provides a simple, cost effective and unobtrusive method of collecting data on energy usage of connected appliances with the aim to

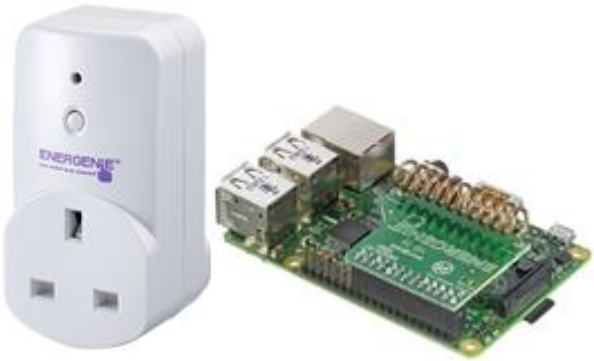
1. Evaluate energy consumption of different appliances
2. Evaluate usage patterns for different appliances

The monitoring system comprises of 2 types of devices – Energenie MiHome Smart Plugs MIHO005 (i.e. Individual Appliance Monitors (IAM)) to sense data relating to power and voltage drawn by the connected appliance, and gateway nodes to collect data from IAM. The key constituents of an IAM system are listed in Table 1. The unit cost of a MIHO005 adaptor and Raspberry Pi-based gateway is £34.99 and £74.17 respectively.

TABLE 1: Key constituents of IAM system

COMPONENT	DESCRIPTION	LINK
Raspberry Pi 3B	Microprocessor for the gateway	https://www.raspberrypi.org/products/raspberry-pi-3-model-b/
ENER314-RT		
Raspberry Pi casing	Casing for Raspberry board	https://www.raspberrypi.org/products/raspberry-pi-3-case/
Energenie MIHO005 adaptor	Individual Appliance monitor	https://energenie4u.co.uk/catalogue/product/MIHO005

The main component of the gateway node is a Raspberry Pi fitted with an Energenie ENER314-RT (receiver-transmitter) add-on board to allow the Pi to communicate with the smart plugs. The data collected by the gateway is stored locally in an SD card as well as sent to the heed-data server hosted in Coventry University through WiFi. Fig. 1 illustrates the design of an IAM system.



(a) (b)

Fig. 1: Constituents of an IAM system (a) IAM (b) Gateway

SOFTWARE IMPLEMENTATION

The IAM are by default programmed to sense energy consumption data in 10-second intervals. The gateway nodes run a program that parses the incoming data to read the sensor ID and timestamp values, compares it to the time of last stored packet for the sensor and records updated values in 1-minute intervals for each monitor. In doing so, the program allows for concurrency by intercepting packets received from all the paired IAMs in the vicinity. Hence, a single gateway can be used to collect data from multiple IAM. Moreover, data from a single IAM may be collected by multiple gateways. The sensed data is stored locally in SD cards as well as communicated to heed-data server hosted at Coventry University.

DEPLOYMENT DETAILS

For the gateway, the ENER314-RT module is fitted to the Raspberry Pi and packaged inside the Raspberry Pi casing. The device is powered through a fixed source and connected to the internet through LAN wires owing to poor Wi-Fi connectivity. The appliance to be monitors is plugged into an IAM, which is, in turn, plugged to a fixed power socket.

For this study, 1 IAM connected to a light bulb and 1 gateway were installed in the male community mobilizer's home in Khalte camp, Nepal, in December 2018 for testing purposes. An additional 62 IAMs and 10 gateways were then installed across 21 households in May 2019. New sockets were installed in the homes that hosted the gateway nodes in order to ensure that the devices were not unplugged for use by another appliance. Upon deployment, the IAM are first paired with the nearby gateway node(s) to set up a network for data transfer. This is done by plugging the IAM in sockets and pressing down the ON button till the ON LED blinks 3 times and turns on. The IAM were labelled with unique identifiers of the format 2379-01, where 2379 is the unique decimal code for the IAM and 01 represents the corresponding gateway to which the IAM is expected to connect. In addition, colored dots and labels were used to map the IAM to the appliance connected to it. This was done to ensure that the appliances are plugged into the same IAM if they were ever unplugged. Fig. 2 shows a Raspberry Pi gateway mounted on a wall and appliances (TV, fan, and phone charger) plugged into IAMs. The GPS location for these devices can be found here.

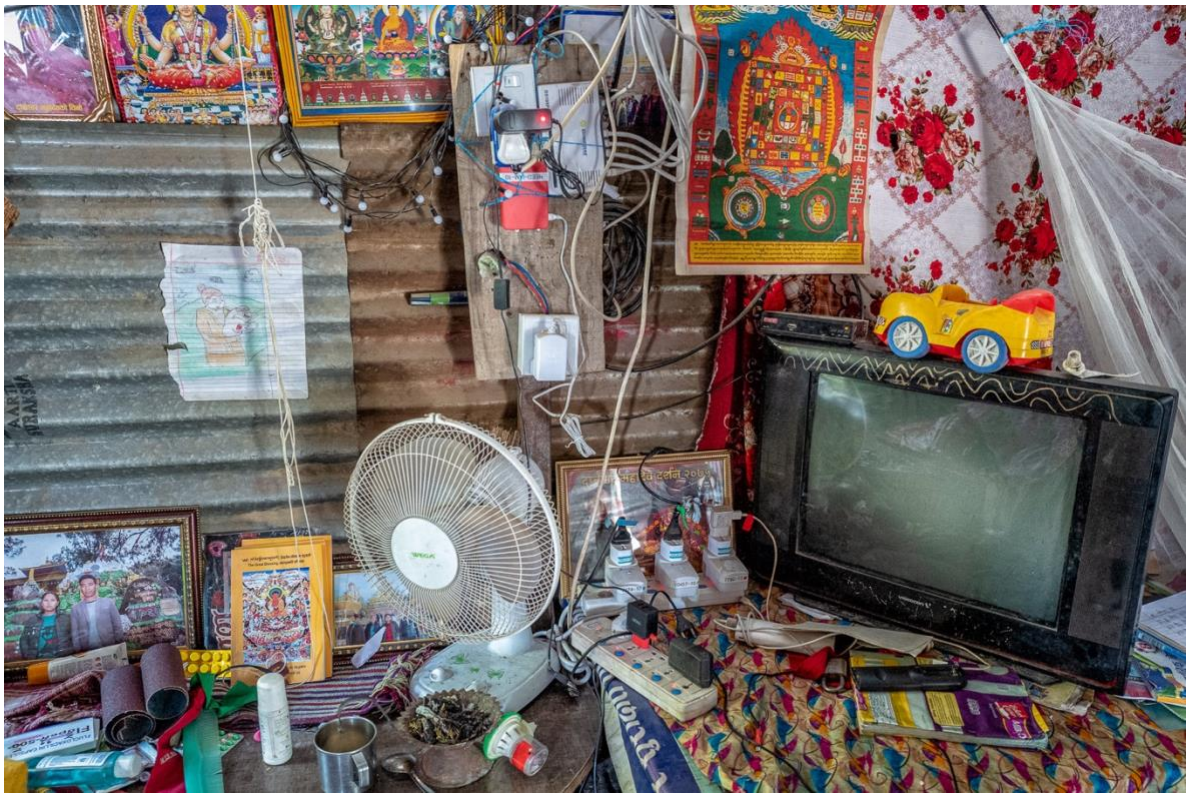


Fig. 2: TV, Fan and Phone charger connected to IAM and communicating data to gateway mounted on the wall.

CHALLENGES FACED POST DEPLOYMENT

1. Power outages: These are common in the camp. Data is lost during this time as the devices have no access to power.
2. Internet connectivity: The availability and reliability of Wi-Fi continues to be an issue for the transmission of data to heed-data server.

DATA ANALYSIS

Table 2 contains the description of data collected by IAM.

TABLE 2: Data collected by IAM

DATA FIELD	VARIABLE NAME	UNITS	DESCRIPTION
Real power	Real power	Decimal format	The real electrical resistance power consumption in the circuit, also known as true power, given in Watts (W)
Timestamp	timestamp	Unixtime	This is in unixtime format (number of seconds since 1st January 1970) and

			displays real time when data is collected. A timestamp conversion tool, such as https://www.epochconverter.com/, can be used to convert the unixtime into a readable format.
Reactive power	Reactive power	Decimal format	The imaginary inductive and capacitive power consumption in circuit given in volt-amperes reactive (VAr)
Voltage	voltage	Decimal format	The difference in electric potential between two points given in Volts (V)
Node ID	sensor	Decimal format	The unique sensor ID for the IAM device.
Frequency	frequency	Decimal format	The nominal frequency of the oscillations of alternating current (AC) in an electric power grid transmitted from a power station to the end-user given in Hertz (Hz)

A sample of data collected by IAM 10850 is shown in Table 3.

TABLE 3: Sample data for IAM

TIMESTAMP	SENSOR	REAL POWER	REACTIVE POWER	VOLTAGE	FREQUENCY
1558784569	10850	0	0	205	50
1558784588	10850	0	0	205	49.9492188
1558784699	10850	0	0	204	49.9492188
1558784757	10850	0	0	202	49.8984375
1558784799	10850	0	0	208	49.8984375

Using the data above, following analysis is intended to be performed.

1. Evaluate energy consumption of difference appliance types.
2. Evaluate patterns of energy usage for different appliances – time of day, daily, weekly, monthly, seasonal.