



Paper- “EXPERIENCES WITH A
HIGH FIDELITY WIRELESS
BUILDING ENERGY AUDITING
NETWORK”

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What this paper is about?

- A wireless sensor network
- Used to monitor electrical usage in a building
- Design, Deployment and Experiences

Motivation behind Paper?

- 72% of total Electrical Energy utilized in residential and commercial buildings
- 30% goes waste

How can we reduce the wastage?

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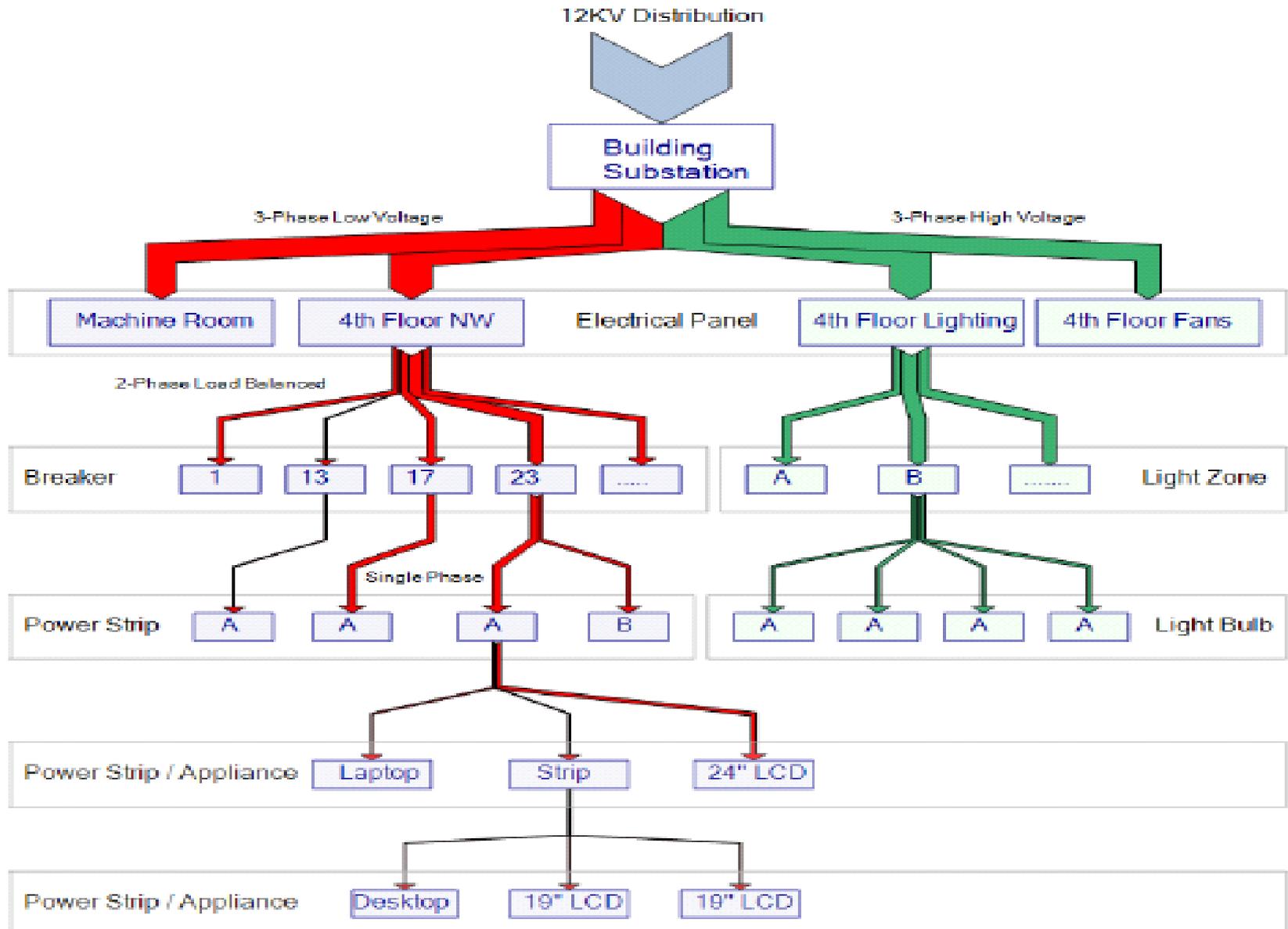
- Need to identify
 - Where it is going waste
 - When it is going waste
- Need to understand
 - How buildings use Energy
 - Over both space and time domain
 - By function, and per-individual

How can we reduce the wastage?

- Need to understand – LOAD TREE
- It helps in determining energy flows
- Helps in devising strategies to measure the energy consumptions in a better way

How can we reduce the wastage?

Load Tree



How can we reduce the wastage?

- Energy meters do provide coverage
- Provide full coverage but not a **detailed** coverage
- We need detailed coverage to realize our goal

Coverage

- Can we get detailed coverage?
- Possible but requires money!!
- So coverage is limited by the number of energy measuring devices.
- Seek ways to improve existing coverage

Improving Coverage

How can we improve coverage?

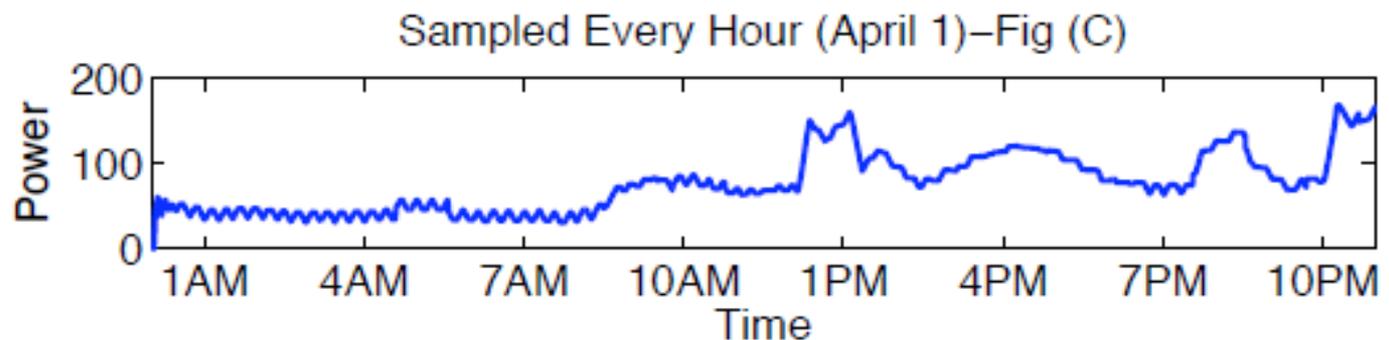
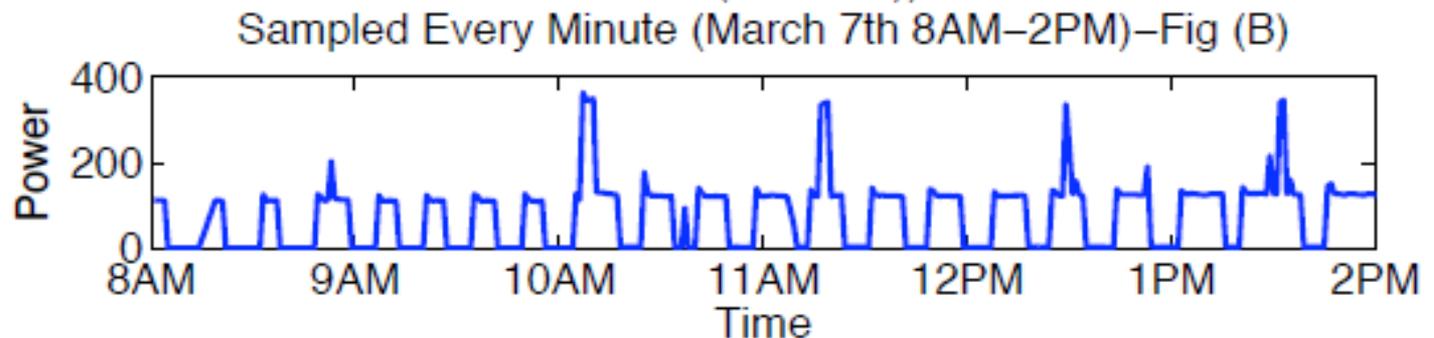
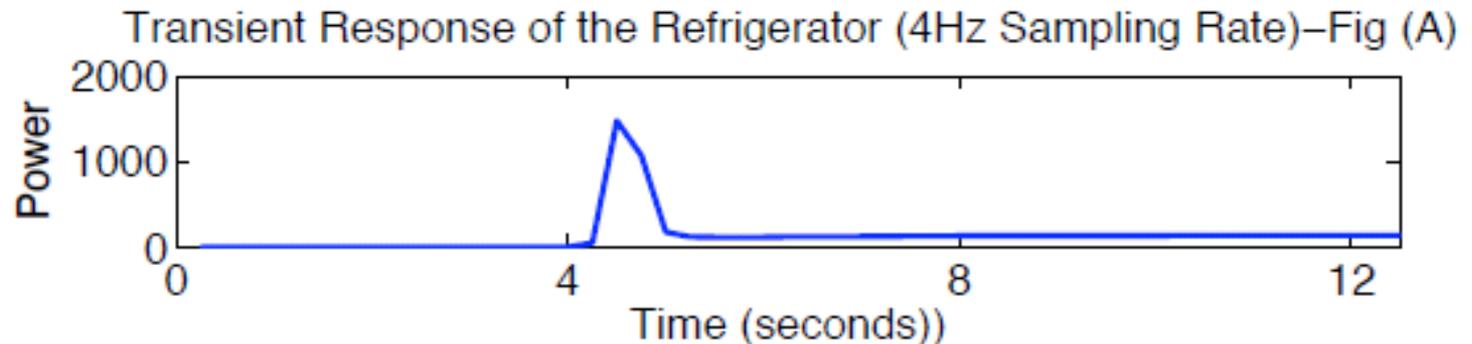
- Need to accurately guess consumption of unmetered devices
- By creating models of the behavior of each unmetered device by using measured data of similar devices.
 - Scale the measured data by using the available aggregate measurement from the parent device

The Data and Sampling

- Model of Appliance behavior is as good as the Data collected
- There are often multiple ways to measure the usage of a single appliance
- e.g. Refrigerator
 - Directly by Power Meter
 - Log of door openings
 - Internal light measurements
 - Record of proximity events
- What behavior should be captured?

The Data and Sampling

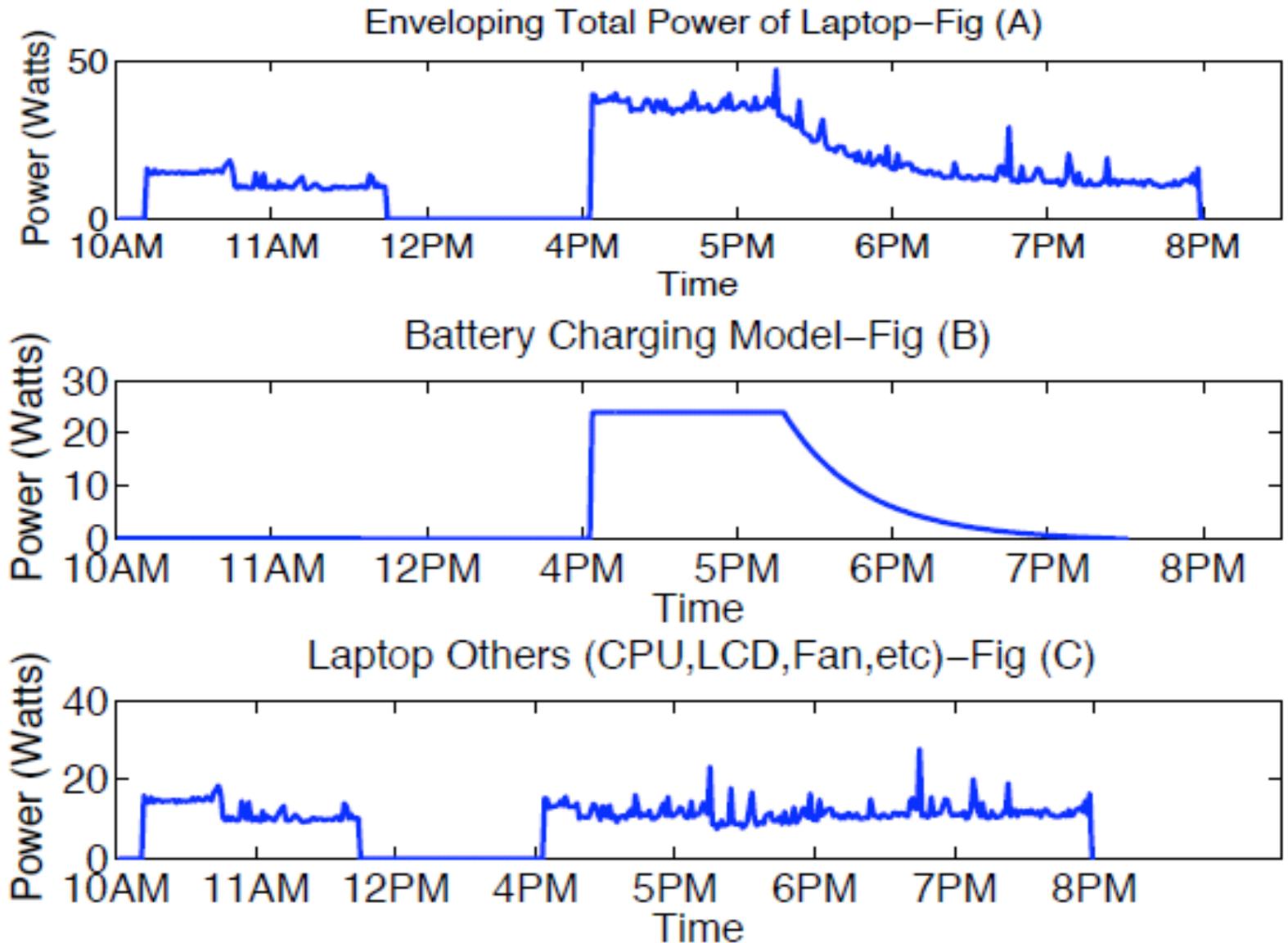
- How often it should be captured?



Appliance Signature Analysis

- Modern electronic devices are a composition of many sub-components
- Natural level of disaggregation at sub component level

Appliance Signature Analysis



Additivity

- Sum of power of children node equals the power of parent node
- Can freely combine a subset of children under the same parent
- Optimal Disaggregation

Decomposition

- By function
 - By space
 - By Individual
-
- Associate Meta-data with each device in a database, such as type of appliance, where it is, and to whom it belongs.

Decomposition by Function

- Just need to sum data from devices of similar type

Decomposition by Space

- Each load in the database- assign x,y and z co-ordinates
- Maintain a database of logical and physical spaces like offices, hallways etc- defined by a bounding box consisting of six planes
- Spatial decomposition- filter load by their co-ordinates
- Still Issues- e.g. Lighting- Illuminate single desk or an entire room- Smoothing techniques

Decomposition by Individual

- Simply sum all the energy consumption for devices belonging to the same owner
- Shared Load?
- *per capita Energy Usage* = $\frac{\text{Energy Consumption}}{\text{No. of Users}}$

Implementation

- Computer Science Lab taken as case study
- Analyze the structure of load tree
- Deploy plug load meters and light sensors to measure energy consumption
- Explore several techniques for maximizing coverage

Energy Monitoring Network

Load Type	Count
Laptops	39
Desktops	28
LCDs	68
Projectors	3
Refrigerators	1
Coffe Makers	1
Phones	3
Desk lamps	5
Network Switches	6
Printers	4
Microwaves	1
Total Appliances	159
Total AC Outlets	340

Energy Monitoring Network

- 38 Wireless AC plug load meters
 - 9 AC meters at power strip level
 - Remaining at appliance level
 - Measured Real and Reactive power at a max sampling rate of 2.8KHz and load power up to 1800 W
- 6 Light sensors

Energy Monitoring Network

- Sensors and Meters part of the wireless ad hoc network
- Transmitted Energy and light readings once per minute to a server via UDP
- Each UDP packet includes:
 - A sequence number
 - Energy used in previous minute
 - Average, Minimum, Maximum and last Instantaneous power in the interval

Energy Monitoring Network

- The server process timestamps the readings and stores them in a database for later processing

Research Project

- Identify devices based on their unique appliance signature