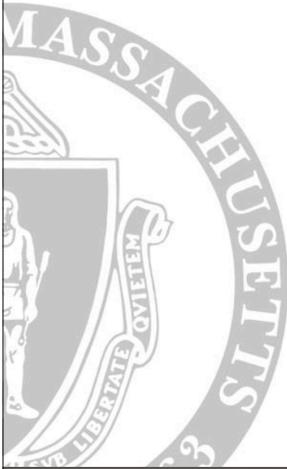


SMART METER ANALYTICS: ENERGY OPTIMIZATION OPPORTUNITIES AND PRIVACY CHALLENGES

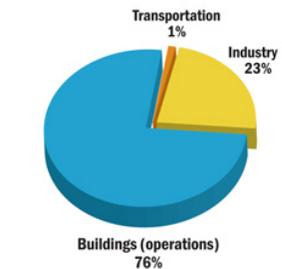


Prashant Shenoy

School of Computer Science

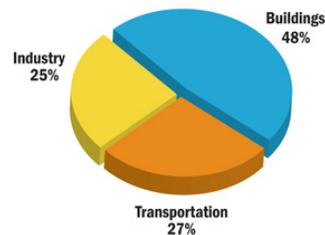
Buildings and Smart Meters

- Buildings are major energy consumers
 - 76% of US electricity, 48% of energy



US ELECTRICITY CONSUMPTION

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Data Source: US Energy Information Administration



US ENERGY CONSUMPTION

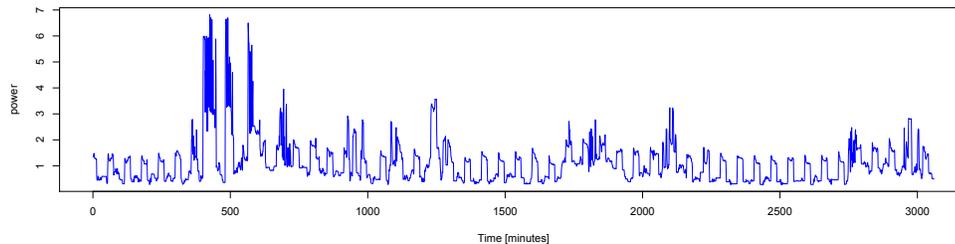
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Data Source: US Energy Information Administration

- Smart meters monitor building electricity usage
 - 37 million smart meters deployed in the USA
 - Benefits: net metering, TOU pricing, fault management,...



Smart Meter Analytics

- Smart meters record data at 5-15 minute granularity
- Fine grain usage data reveals wealth of information

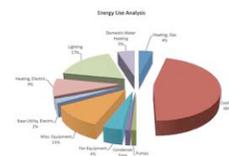


- Companies deploying “big data” energy platforms
 - Mine customer data to gain profitable insight
 - Use in marketing campaigns or provide recommendations

What kind of analytics are possible?

▪ Utility-scale analytics

- Break-down a customer usage by load types
 - Flag higher than average categories
- Disaggregation: what appliances are present in a home?
- ROI analysis: should an inefficient appliance be replaced?
- Will a transformer overload during a summer heat wave?



▪ On-premise customer analytics

- Notify when laundry cycle has finished
- Notify when energy spent in heating the home > threshold
- Analyze usage to decide when to defer elastic loads

- **Benefit:** Deep insights *without* deep instrumentation!

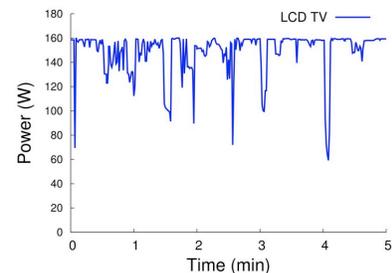
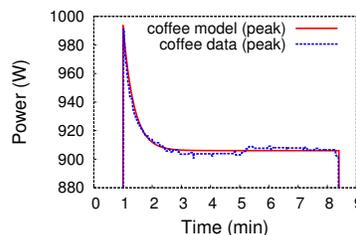
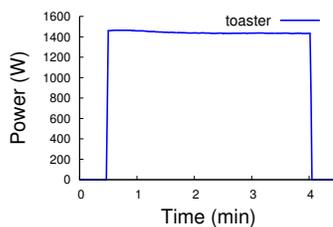
Smarter Models for Smarter Analytics

- **Model-driven analytics**
 - Derive models of load behavior and usage patterns.
 - Model and predict energy usage
- Approach: models of electrical loads in homes
 - Use electrical properties of load to model them
- Resistive, inductive, non-linear loads



Modeling Residential Electrical Loads

- Resistive loads: on-off model
- Inductive loads: on-off decay-growth
- Non-linear loads: stable min-max
- Complex loads: composition of basic model types



Utility Case Study

- Working with local municipal utility
 - 18,000 smart meters across entire user base.



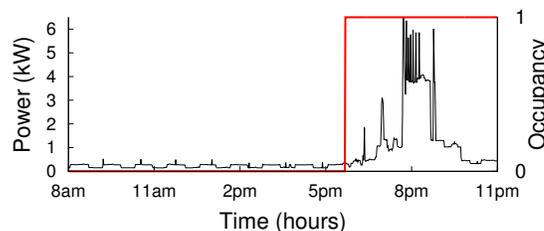
- Analytic techniques to:
 - Identify occupancy patterns in the home
 - Detect HVAC usage in the home



- Detect misprogrammed or misaligned thermostats
- Can derive personalized schedule for each home
 - aligns with occupancy
 - reduces energy waste

Smart Meters Leak Private Data

- Smart meters reveal human activity data
 - When are occupants away or on vacation?
 - Do occupants eat out on weekends?
 - Do they have an infant in the home?



- Can mine information through side-channel attacks
- Challenge: how to preserve privacy of individuals while enabling smart meter functionality?

Privacy Preserving Smart Metering

- Spectrum of approaches with different tradeoffs
- Never send data, instead take send verifiable proofs of actions (total usage, DR,...) [*Buildsys'10*]
 - Needs smart meters to be enhanced with crypto protocols
- Send all data, but obfuscate [*Percom'14*]
 - Privacy enhancing appliances (water heater) obfuscate data to prevent analytics
- Controllable privacy
 - Reveal select data with appropriate loss of privacy

Conclusions

- Rich analytics possible over smart meter data
- Wide ranging benefits when data is used appropriately
- But data is prone to 'misuse' or privacy leaks
- Balanced approach that provides many benefits in a privacy preserving manner
- Acks: D. Irwin, S. Barker, A. Mishra, S, Kalra