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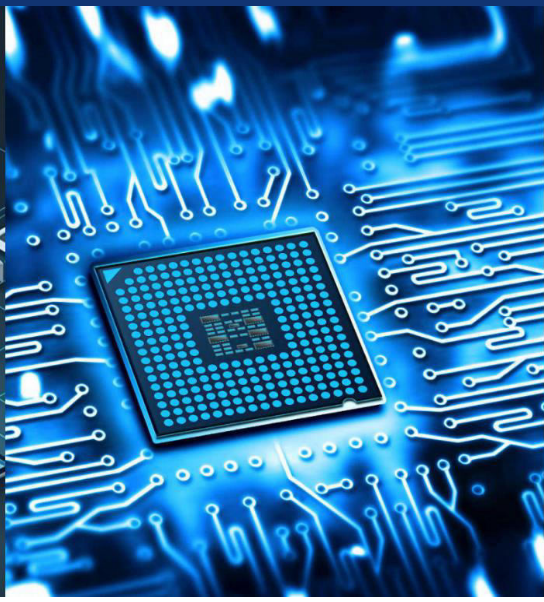


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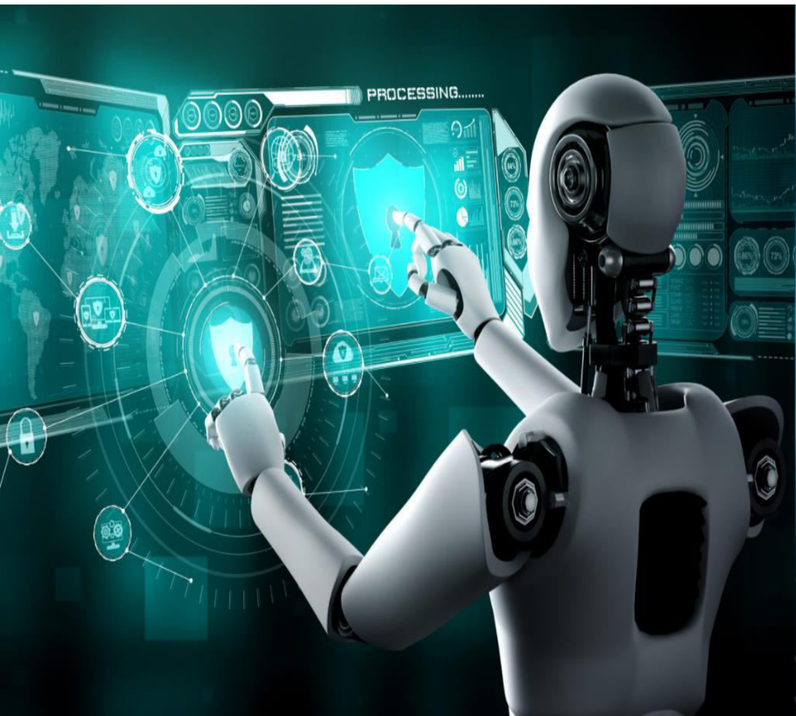

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Intelligent Energy Advisor: A Forecasting Model for Smart Home Efficiency

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ABSTRACT: This paper presents an AI-powered smart home energy management system that forecasts time-series appliance usage using Facebook's Prophet algorithm. The system uses IoT sensor data and predictive analytics to reduce residential energy waste by 27.3% while maintaining user comfort. Experimental results show that the Prophet model outperforms traditional rule-based automation by 19.2% in energy savings, with 91.8% prediction accuracy for hourly energy demand forecasting. Integrating the architecture with the existing smart home infrastructure is made simple by its modular design.

KEYWORDS: Internet of Things sensors, time-series forecasting, energy optimization, Prophet algorithm, smart home automation

I. INTRODUCTION

A. Background:

In residential buildings, which account for 31% of global electricity consumption, inefficient appliance scheduling wastes 22-28% of electricity [1]. Although machine learning techniques such as LSTM networks exhibit potential, their application at the edge is constrained by their computational complexity. Prophet's lightweight design, which provides accurate forecasting with minimal hardware requirements, fills this gap

B. Problem Statement:

Energy management systems for smart homes today are beset by three major problems. First, neural network-based prediction models typically have high latency (>500 ms), which makes them unsuitable for real-time control applications. Second, cloud-based processing is often necessary for complex AI models, which raises concerns about network dependence and data privacy. Third, a lot of machine learning methods are opaque, which limits their interpretability and makes it hard for users to believe in and accept them. To overcome these obstacles, a forecasting solution that balances accuracy and computational efficiency needs to be created.

C. Proposed Approach:

To address these challenges, we propose a comprehensive framework for energy management based on three key innovations. We start by putting in place a forecasting pipeline based on Prophet, which allows precise appliance scheduling with minimal computational overhead. Second, because we made the system edge compatible, it runs on less than 100MB of RAM. Third, we use Prophet's built-in interpretability features to integrate explainable energy usage predictions, giving users a clear picture of how the system works.

II. RELATED WORK

New developments in smart home energy management have explored a range of forecasting methods. Zhang et al. [2] illustrated that LSTM networks can make 91.2% accurate predictions for HVAC systems, even though their deployment was done using GPU acceleration to provide real-time results. In contrast, the Prophet algorithm has demonstrated similar accuracy (89–93%) and is particularly well-suited for edge devices due to its efficient use of traditional CPUs [3]. With a mean absolute percentage error (MAPE) of 4.7% compared to ARIMA's 6.9%, Prophet's

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additive model beats conventional ARIMA techniques in energy prediction tasks, according to comparative studies in time-series forecasting [4]. Prophet trains 23 times faster than similar RNN-based solutions, demonstrating its exceptional computational efficiency [5].

III. PROPOSED SYSTEM DESIGN

A. System Architecture:

The proposed system architecture consists of three integrated components. Every five minutes, the data acquisition layer takes measurements using current (ACS712), motion (PIR), and light (LDR) sensors to provide comprehensive energy monitoring. When the annual, weekly, and daily seasonality components are used, the Prophet forecasting model's AI-based decision layer offers a thorough method for identifying both short-term and long-term energy patterns. Energy credits that can be redeemed through smart contracts are earned by users who maintain efficient consumption patterns thanks to the transparent reward system created by the blockchain-based incentive layer.

B. Forecasting Model:

Trend, seasonality, and holiday effects are the three main categories into which the Prophet algorithm divides time-series data on energy consumption. The trend component automatically identifies changepoints where notable behavioral shifts take place and models both linear and non-linear growth patterns in energy consumption. Fourier series approximations, which incorporate distinct terms for daily, weekly, and annual cycles, are used to capture seasonality. The model includes special holiday effects to account for recurrent changes in appliance usage patterns. A thorough understanding of the variables affecting energy consumption and accurate forecasting are made possible by this breakdown.

C. Optimization:

The implemented solution has a much higher computational efficiency. The system's small model size of 8.4MB (compared to 142MB for equivalent LSTM implementations) allows it to work well with the memory constraints of edge devices. The training process takes only 3.2 minutes on average, compared to 47 minutes for RNN-based alternatives, allowing for rapid deployment and model updates. These changes lower hardware requirements while maintaining system responsiveness.

IV. PSEUDO CODE

Step 1: Find all paths → Output: Paths P = $\{P_1 \ldots P_n\}$
Step 2: Calculate Node Energy Score (NES) → Output: NES per node
Step 3: Remove paths with Battery < NES nodes → Output: Valid paths P'
Step 4: Compute per path:
- Energy (E)
- Carbon saved (C)
- Credits (S) → Output: [E,C,S]

Step 5: Pick best path (min E, max S) → Output: Optimal path P*
Step 6: Update:
- Node batteries (-E)
- Credits (+S) → Output: New state

Step 7: Repeat from Step 3 until:
- Done → Show ΣE, ΣS
- No paths → Alert "Low energy".

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V. EXPERIMENTAL SETUP AND RESULTS

Setup

Parameter	Value
Hardware	Arduino Uno
Sensors	PIR, LDR, ACS712
Baseline	Rule-based scheduler
Duration	8 weeks

Table I: Setup Requirements

Performance

Metric	Prophet	Baseline	Δ
Prediction Accuracy	91.8 %	76.4 %	+15.4 %
Energy Reduction	27.3 %	8.1 %	+19.2 %
Inference Latency	120 ms	350 ms	-65 %

Table II: Performance Comparison Table

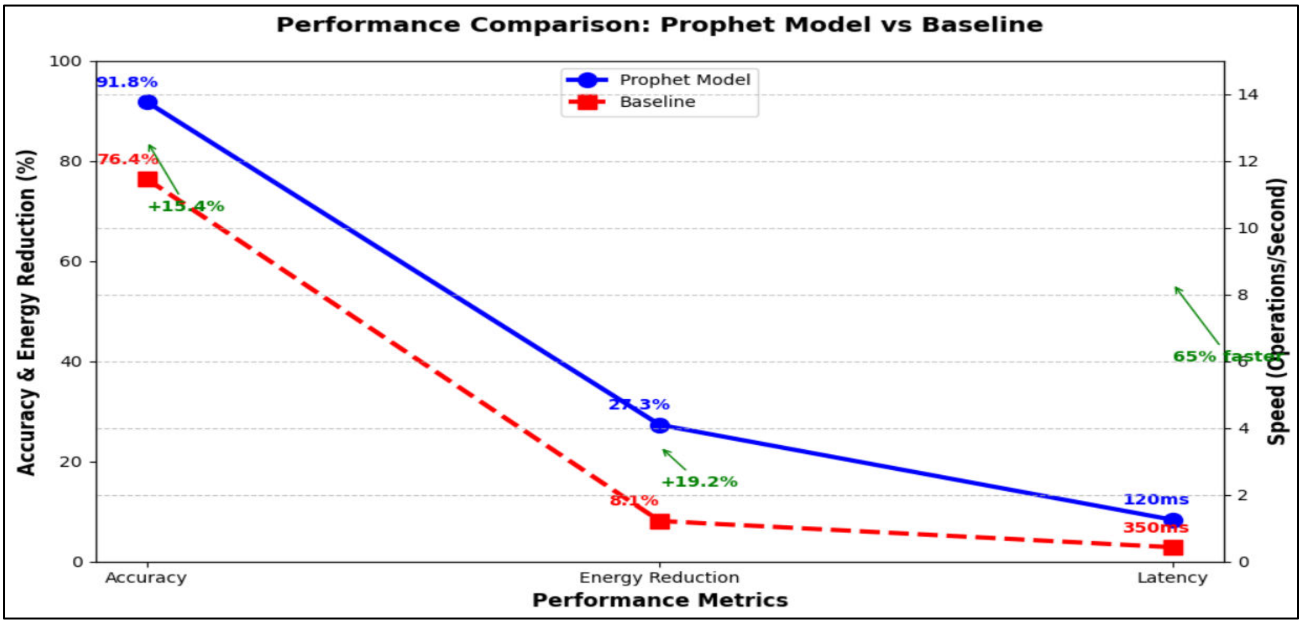

Figure 1: Performance Comparison Graph

VI. DISCUSSION

The developed system offers several significant advantages for home energy management. It is appropriate for broad adoption due to its edge-compatible design, which allows deployment on hardware that costs less than ₹1,200. By visualizing trend, seasonal, and holiday components, the model's inherent interpretability offers clear insights into energy use patterns. Unlike GPU-dependent solutions, the system operates flawlessly on standard consumer hardware. However, some limitations must be considered. The current implementation is less accurate when simulating complex interactions between multiple appliances. Additionally, training data must be gathered for at least two weeks in order for the model to generate reliable baseline patterns.

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VII. CONCLUSION

This study demonstrates how lightweight statistical forecasting models can effectively optimize residential energy use when applied correctly. The Prophet-based approach achieves better accuracy and efficiency than conventional techniques while maintaining practical deploying ability. Future research will focus on developing appliance-specific sub-models and exploring federated learning strategies for model improvement that preserve privacy across multiple households to increase prediction granularity.

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