The Road to Web 3.0: Empirical Insights into Full Node Workload in the Bitcoin Blockchain

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Introduction

- Overview of Web 3.0
  - Often called the "decentralized web"
  - Marking a shift from centralized databases to blockchain
  - Restore data ownership and control to individuals
  - Draws attention amid data privacy concerns
  - Public blockchain-based applications on the internet: Bitcoin etc.
- Functions of Full Nodes
  - Maintain complete blockchain records
  - Process various transactions
  - Essential for blockchain robustness and security

Introduction

- Operating Full Nodes
  - Requires a computer with substantial specifications
    - Storage, Processing power, RAM
  - Can Consume significant bandwidth
    - Leads to high data costs in some regions
  - Requires constant power to remain operational

Related works

- Parlikar et al. studied feasibility of energy-efficient blockchains using proof-of-stake (PoS) networks instead of proof-of-work (PoW).
- Tomatsu et al. examined Bitcoin mining's energy consumption and potential use of renewable energy.
- Taherdoost et al. assessed blockchain adoption in healthcare, highlighting its efficiency and cost-effectiveness.
- **Our Work:** Focused on Bitcoin core module resource usage, differing from studies on mining nodes.

Experiment Design: Bitcoin Full Nodes

- Analyze vital matrices
  - Analyze Power Consumption
  - Analyze Bitcoin Packets
  - Analyze Node Geographic Locations
- Experiment on different type of nodes
  - Desktop Computer
  - Single-board Computer (Orange Pi)

Experiment Design: Stages

1. Stage-1: Network Packet Analysis with Wireshark:
   - Run the Bitcoin full node on the target device.
   - Use Wireshark to listen on port 8333.
   - Experiment on both nodes.
2. Stage-2: Power Consumption Measurement:
   - Run the Bitcoin full node on the target device.
   - Use Power meter (Figure 1) to monitor power.
   - Experiment on both nodes.
   - Capture image of the power reading every 1 minute.

Figure: Power Meter PN2000 by Poniie

Experiment Design: Phases

We executed both stages in two phases:

1. Phase-1: During Sync Process: When the Bitcoin full node is initially being synced.
2. Phase-2: After Sync Process: After initial sync, we kept the node running for 80 hours (appx.)

Experiment Design: Summary

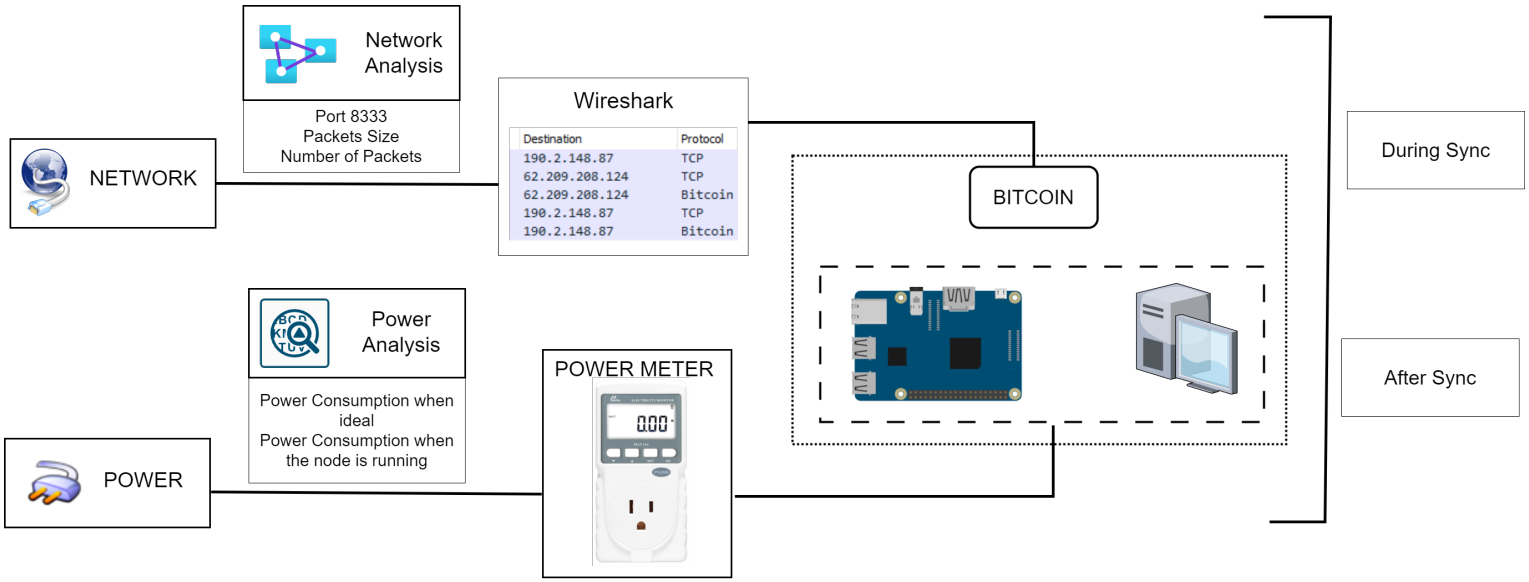


Figure: Full Experiment Setup.

Data Processing: Network Data

- **Wireshark**
  - Used wireshark to monitor port 8333
  - Wireshark produced PCAP files
  - Converted to Pandas Dataframe using Tshark and Pandas
  - Revealed packet content, packet type, size, headers etc.
- **Geo location**
  - Used ipinfo.io api to retrieve Geo locations of source and destination
  - Plotted the unique Geo locations on map using Folium library.

Data Processing: Power Data

- We took periodic image of the reading.
- OCR using Tesseract.
- Tabular format with power and time.
- Power recorded in Watt
- Power meter resolution: 0.01W

Results: Bitcoin packets

- Bitcoin protocol introduced Addr v2 in 2019.
- Addr v2 supports IPv6, Tor v3, and other types of network addresses.
- Percentage of Addr and Addr v2.
- Combined phases (During and After sync).
- Reported for both nodes.

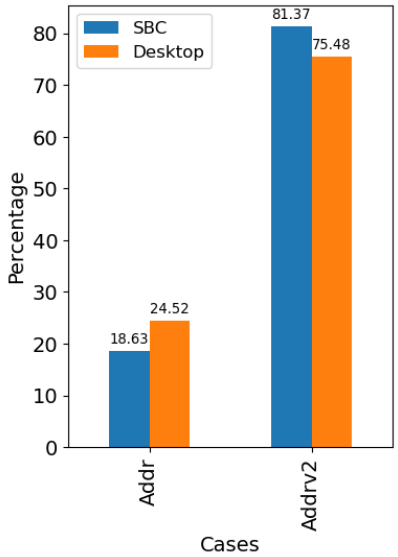


Figure: Addr and Addr v2 comparison

Results: Bitcoin packets Data consumption

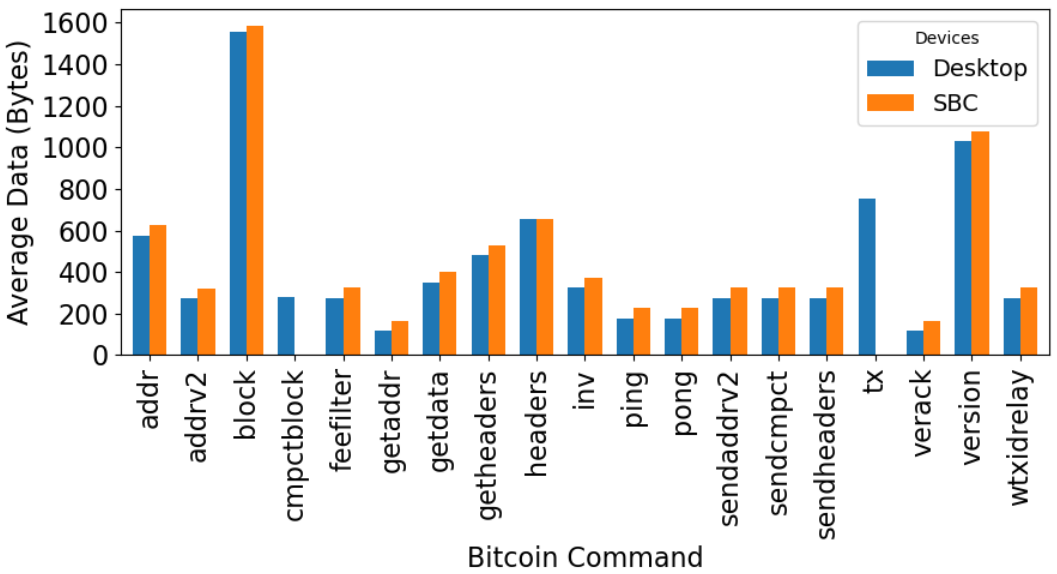
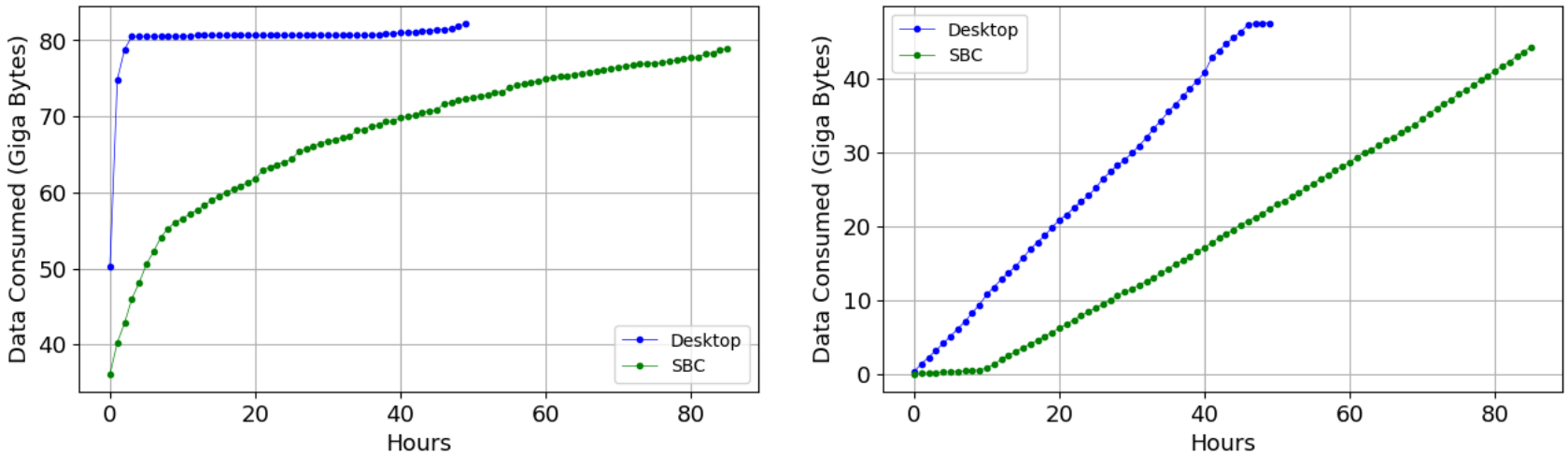


Figure: Comparative Sizes of Packets

- Comparative Sizes of Packets
- Received by Desktop and SBC Devices
- During the Full Experiment

Results: Data Consumption Comparison

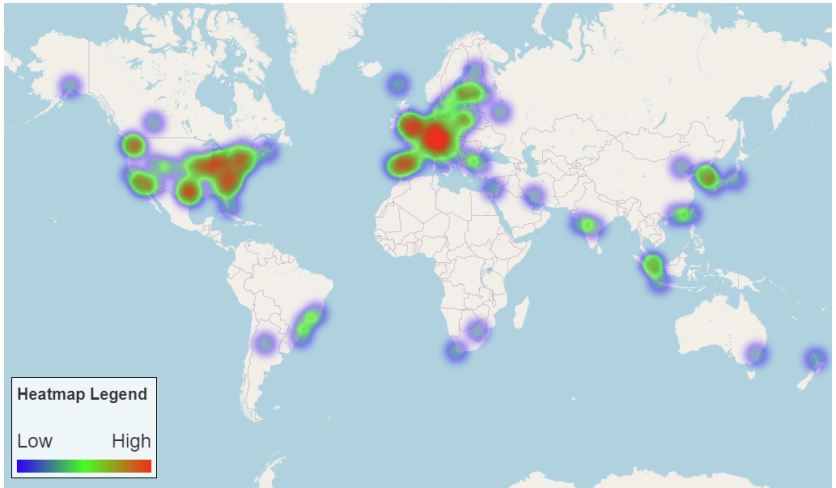


(a) During Initial Sync process.

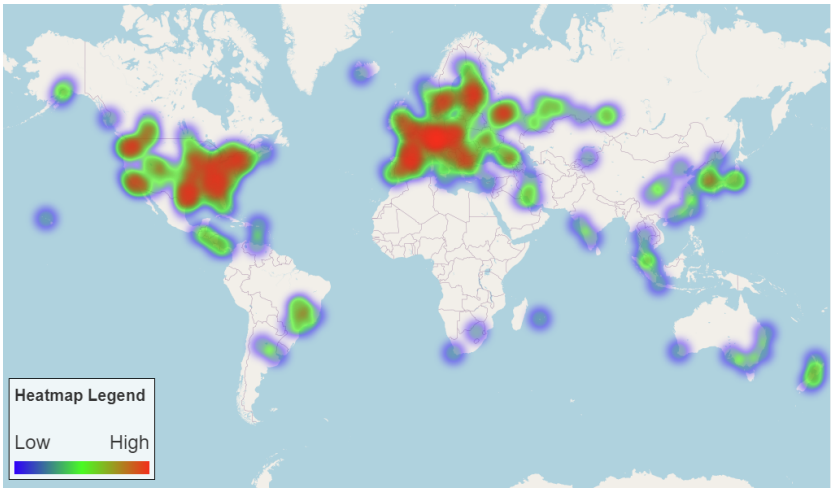
(b) After Initial Sync process.

Figure: Approximate Accumulated Data Consumption by the Devices During and After the Initial Sync Process.

Results: Full node locations



(a) Desktop Node During Sync.



(b) Desktop Node After Sync.

Figure: Heatmap Visualization on Maps, Showcasing Geolocated Incoming Ping Messages Captured by a Bitcoin Node, with IP Addresses Reverse Geo-coded to Latitudes and Longitudes on the Desktop Node.

Results: Power Consumption

- Desktop and SBC Power Usage in Watts.
- For better comparison, used Log scale.
- SBC uses significantly lower power.

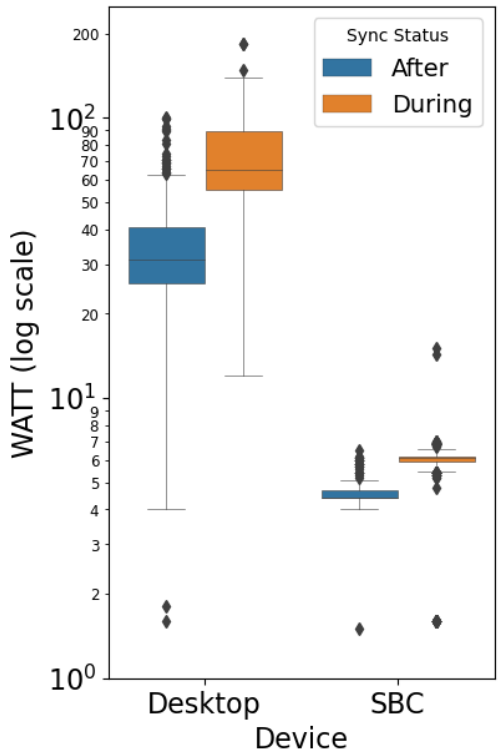
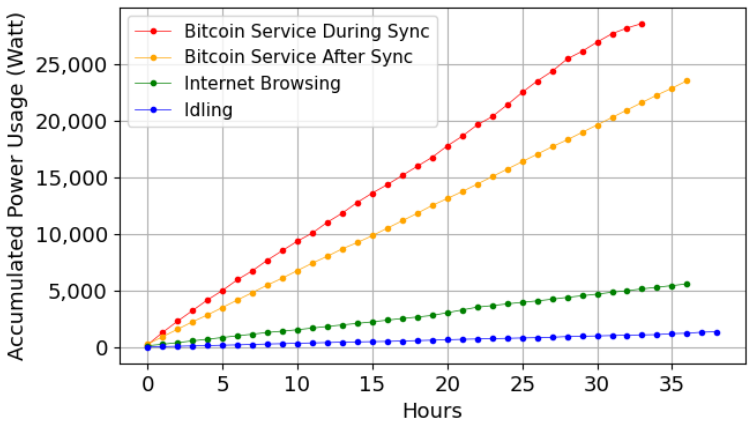
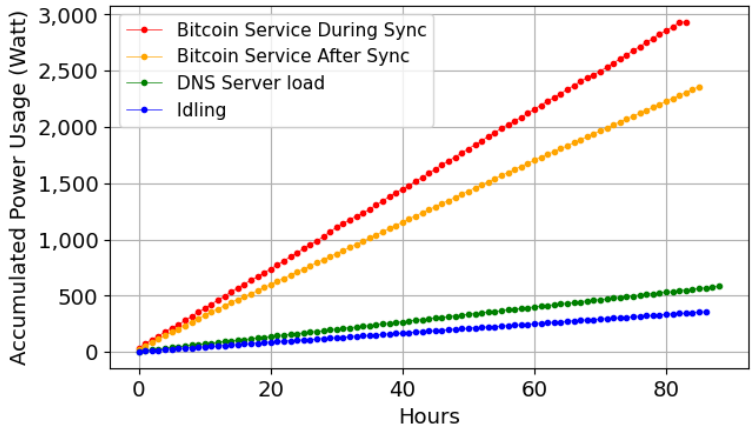


Figure: Power usage box plot

Results: Power Consumption Comparison



(a) Desktop Power Consumption Comparison.



(b) SBC Power Consumption Comparison.

Figure: Approximate Accumulated Power Consumption for Different Scenarios.

Conclusion

- Navigated operational intricacies of Bitcoin Core full nodes across diverse hardware.
- Analyzed Bitcoin packets on different devices: desktop computer and Single Board Computer (Orange Pi).
- Studied power consumption during and after initial synchronization.
- Examined global node distribution by reverse engineering IP addresses.
- Delved into packet patterns, global node distribution, and power consumption.
- Offers unique insights into the real-world challenges of blockchain.

Thank You!

Have any questions?