Applications of Blockchain to IoT Security

Presenter: Roshan Singh

Facilitators: Abdul Rahman Sattar, Ikjot Saini

24th September, 2020

aisc

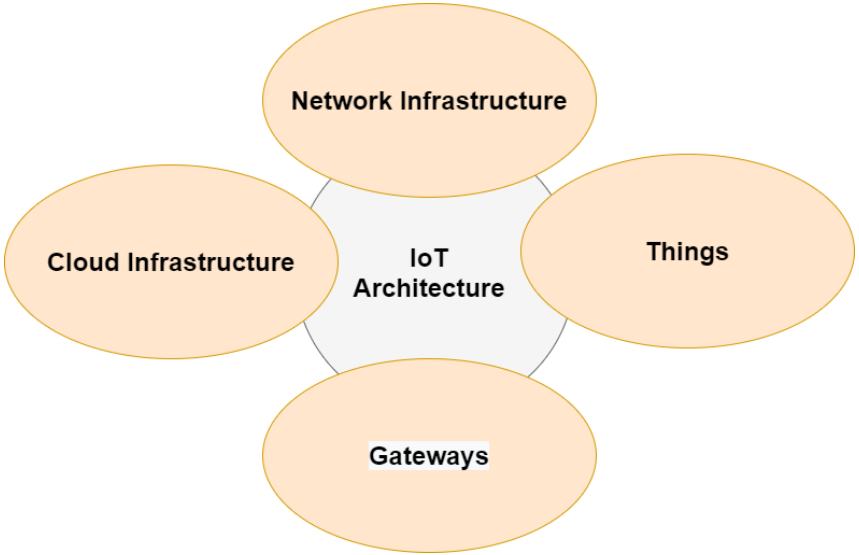
IoT

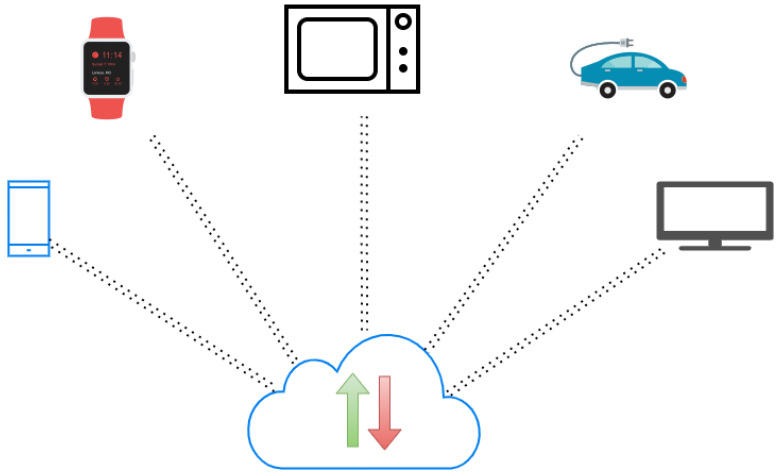
Image Source: *e-zigurat.com* Link

Some applications of IoT

1. Smart Homes
2. Autonomous Vehicles
3. Wearables
4. Healthcare

Centralised IoT Architecture





Characteristics of Centralised IoT Architecture

1. Centralised Device Authentication
2. Centralised Access Control
3. Centralised Device Registration and Revocation.

Challenges in Centralised IoT Architecture

What if the Central Authority becomes unavailable ?

1. User has limited or no control over his data
2. Lack of assurance against availability of service
3. Lack of incentives to the user

Other Challenges in IoT Systems Deployment

1. Lack of Standardization of IoT devices.
2. Availiability of diverse range of protocols.
3. Most IoT devices has no privacy assurance.
4. No inherent common platform for data sharing among these devices

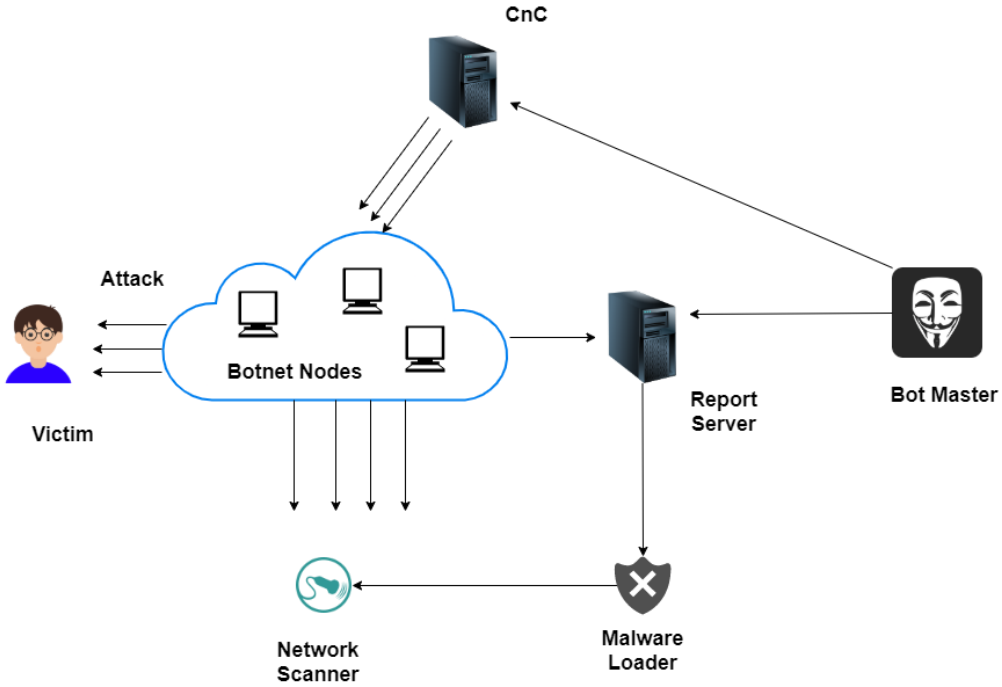
Common Attacks on IoT Systems

1. DDoS.
2. Replay Attack.
3. Remote Code Execution.

Mirai Botnet [1]

- Infected around 600k IoT devices
- Targeted IoT devices and embedded systems
- Major targets were, Krebson Security, OVH and Dyn and some gaming servers.

Mirai Botnet Workflow



How Blockchain can help improve IoT Security ?

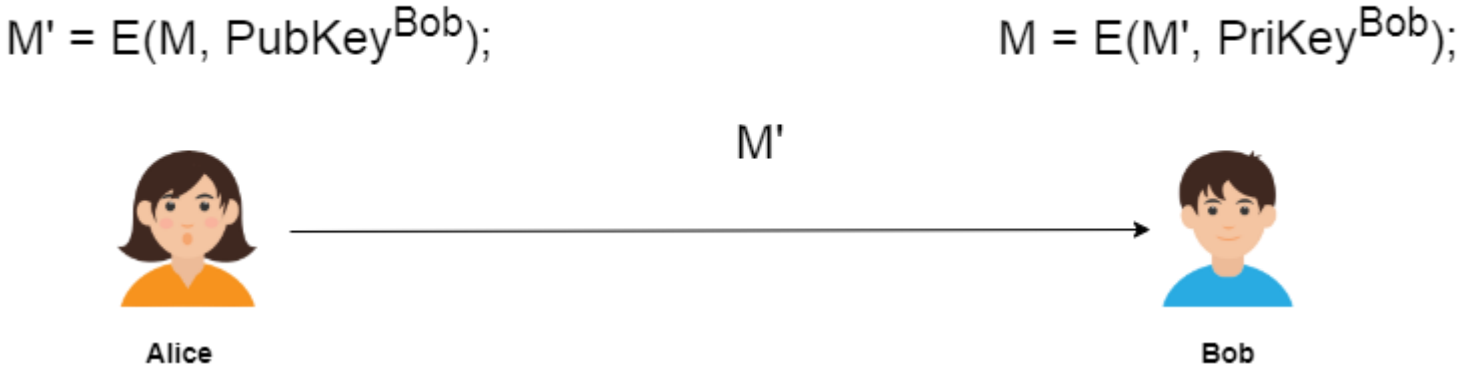
1. Provide devices a common platform for secure data exchange.
2. Eliminate the dependence on the Central Authority.
3. Automate decision making process with the help of Smart Contracts.

What is a Blockchain ?

- **Definition 1**: A Blockchain is a growing list of records, that are linked using **cryptography**. Each block contains a cryptographic hash of the previous block, a timestamp, and transaction data(generally represented as a **Merkle Tree**). (Source: *wikipedia.org*)
- **Definition 2:** A Blockchain is an **open distributed** ledger that can record transactions between two parties efficiently and in a **verifiable** and **permanent** way. (*Iansiti, Lakhani 2017*)

Fundamentals of Blockchain

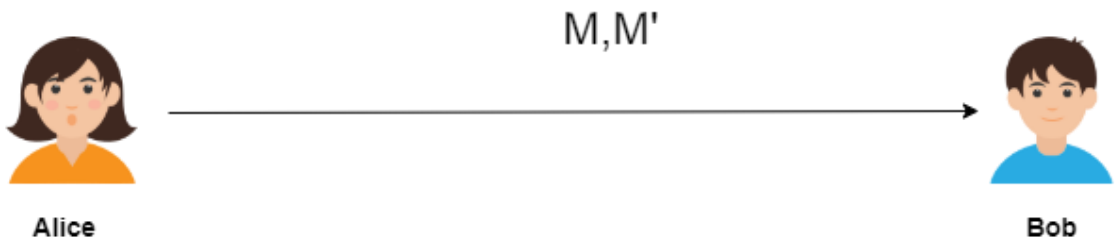
- Public Key Infrastructure



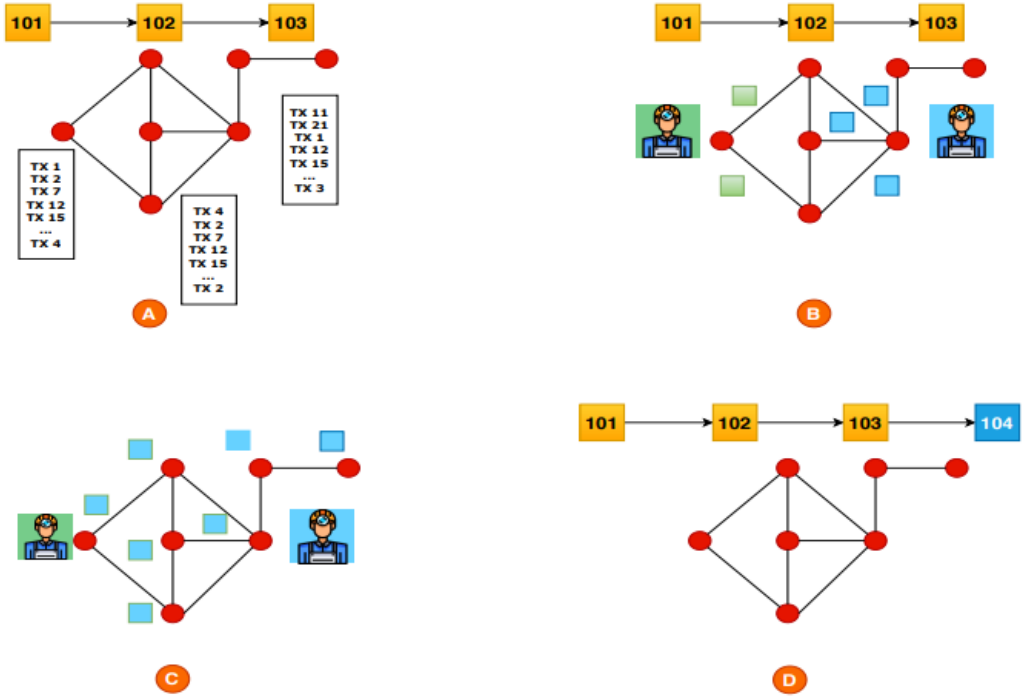
Fundamentals of Blockchain

- **Hash Function**:
  - M : Message (Variable Length)
  - H : Hash Function
  - Hash of M = H(M) (Fixed Length)

$M' = E(H(M), PriKey^{Alice});$ $H(M) = E(M', PubKey^{Alice});$



Consensus in Blockchain



Use Case 1: Smart Homes

Paper : Managing Smart Home Appliances with Proof-of-Authority and Blockchain. **[2]**

Authors: Pranav Kumar Singh, ***Roshan Singh***, Sunit Kumar Nandi and Sukumar Nandi.

2nd Best Paper Award, i4CS 2019, Germany

Managing Smart Home Appliances with Proof of Authority and Blockchain

Pranav Kumar Singh[1,2(✉)], Roshan Singh[2], Sunit Kumar Nandi[1,3], and Sukumar Nandi[1]

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Abstract. With the advance in technology and growth in standard of living, smart homes have become a reality. Smart homes consist of home appliances and devices that communicate with each other to address the needs of the residents. These appliances generate, share and consume lots of data which are private and sometimes safety critical to the residents. Managing them is a challenging task. The current frameworks for managing home appliances are centralized in nature. Such frameworks force smart home residents to trust the service providers or a third party. These frameworks are also prone to hacking, compromise of data and a single point of failure. Availability of services can also never be guaranteed with such frameworks. Technologies such as blockchain and smart contracts can help to manage these appliances. In this paper, we study the scope of blockchain technology in smart homes. We propose, implement and evaluate a blockchain based approach using Proof-of-Authority as the consensus mechanism for managing appliances in smart homes. In addition, we compare the performance of our system with the traditional Proof-of-Work based system.

1 Introduction

Smart home, a popular use case of Internet-of-Things (IoT) [7] consists of a range of home appliances of various applications and heterogeneous electronic devices enabled with computing and communication technologies. These appliances and devices aim to automate domestic works by harnessing their sensing and computational capabilities, utilizing the resources efficiently by sharing information with others. A smart home can incorporate appliances such as smartphones, smart television, smart AC, smart cooker, smart water purifier and other IoT-enabled devices such as motion sensors, thermal sensors, humidity sensors to name a few. A combination of these appliances and devices to a particular home

Use Case 1: Smart Homes

Key Contributions:

1. Propose a blockchain based Home Appliance Management framework.
2. Perform Testbed Experiment
3. Compare the performance of proposed blockchain based system with challenge response v/s voting based consensus mechanisms.

Managing Smart Home Appliances with Proof of Authority and Blockchain

Pranav Kumar Singh[1,2(✉)], Roshan Singh[2], Sunit Kumar Nandi[1,3], and Sukumar Nandi[1]

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Use Case 1: Proposed System Model

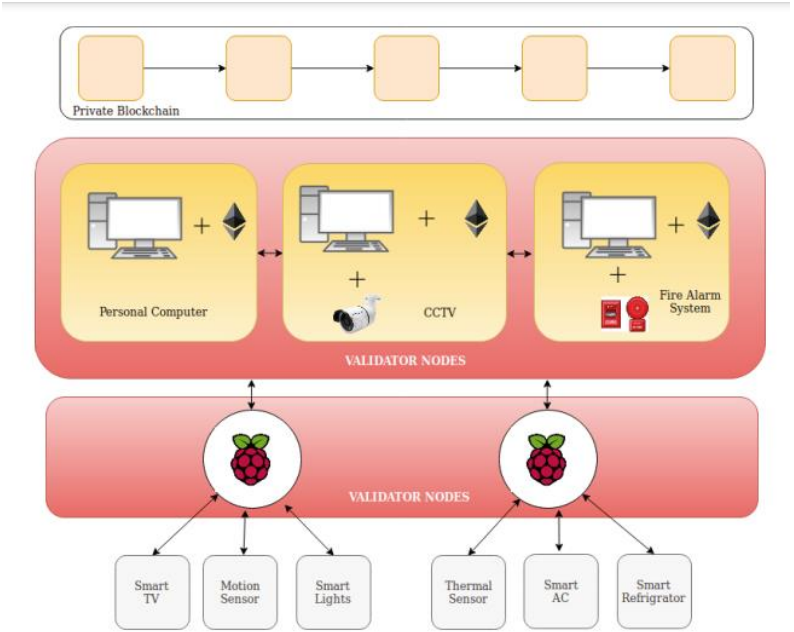

Fig. 1. Proposed system model

Use Case 1: Testbed Setup

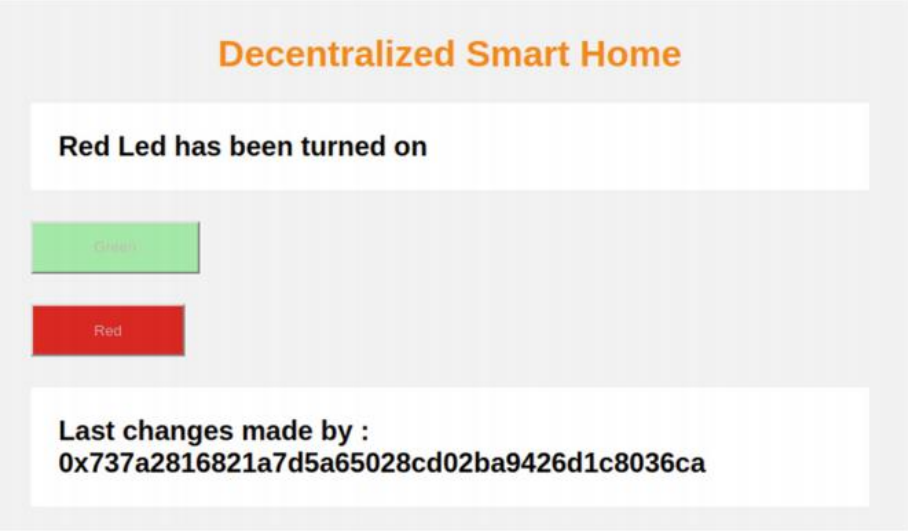

Fig. 4. Our developed smart home application

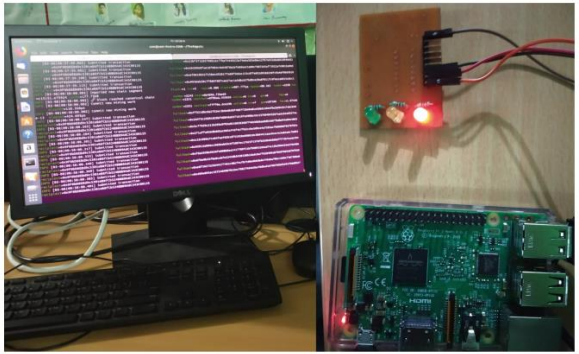

Fig. 2. Validator nodes and processing unit setup

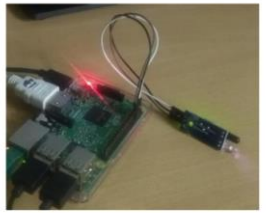

Fig. 3. IR sensor interfaced with processing unit

Use Case 1: Experimental Details

Table 1. Devices and their role

Device name	No. of device	Geth version	Role
Dell-Vostro (8 GB RAM, i7-7700 CPU, 1 TB HDD)	1	v1.8.17-stable release	Validator
Raspberry Pi 3	1	geth 1.8.18 ARMv7	Validator (Processing Unit)
IR Sensor	1		Home IoT device
LED	2		Home appliance
nodeMCU	1		Home IoT device

Use Case 1: Results

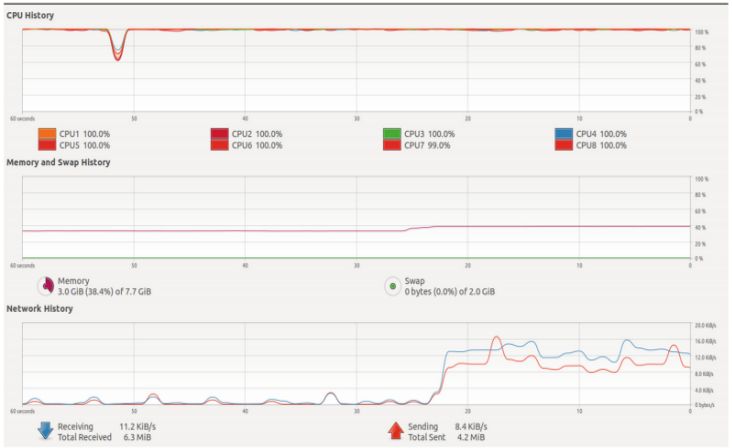

Fig. 6. Performance with Proof-of-Work

Fig. 7. Performance with Proof-of-Authority

Use Case 1: Key takeaways

- A voting based consensus mechanism is much efficient in terms of resource consumption, transaction acceptance time in compare to challenge response based mechanism.
- Such a system enables home appliances for localised decision making, without sending the data to the cloud service providers.
- Better control and monitoring of home appliances

Use Case 2: Decentralized Parking Management

Paper : Smart Contract Based Decentralised Parking Management in ITS. **[3]**

Authors: Pranav Kumar Singh, ***Roshan Singh***, Sunit Kumar Nandi and Sukumar Nandi.

Smart Contract Based Decentralized Parking Management in ITS

Pranav Kumar Singh[1,2(✉)], Roshan Singh[2], Sunit Kumar Nandi[1,3], and Sukumar Nandi[1]

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Abstract. Providing a better experience to the drivers is one of the core objectives of implementing Intelligent Transportation Systems (ITS). ITS aims to offer a range of services for making the life of drivers more comfortable. However, the way these ITS related services are implemented until now is centralized and is somewhat cumbersome. Centralized approach for implementing ITS services make the customers and the stakeholders of the services trust and depend on various intermediaries. Moreover, such an approach is often prone to a single point of failure which affects the availability of the services. Decentralized technologies such as Blockchain and Smart Contracts can help address such issues. In this paper, we study the scope of Blockchain Technology in implementing ITS related services. We design a decentralized system for Parking Management in ITS using Smart Contracts. We implement our proposed system on the Ethereum blockchain platform to demonstrate its feasibility.

1 Introduction

With the rise in the number of smart vehicles on the road, Intelligent Transportation Systems (*ITS*) is becoming a necessity. *ITS* is the application of information and communication technologies which enhances transportation safety, mobility, reduces traffic congestions and pollution [17]. *ITS* provide drivers better driving experience by providing a range of communication services such as travel and traffic management services, electronic payment services and infotainment services to name a few. With time the number of smart vehicles on the road is increasing, and so the parking-related problem is [6]. The problem is much more prominent in urban areas where finding space for parking is much more difficult and frustrating to the drivers. Often drivers need to circle a parking area several

Use Case 2: Decentralized Parking Management

Contributions:

1. Provide an individual a common and a decentralized platform to monetize his unused resources.
2. Bring into transparency and increase availability of the system.
3. Establish trust among the untrusted parties in the ecosystem.

Smart Contract Based Decentralized Parking Management in ITS

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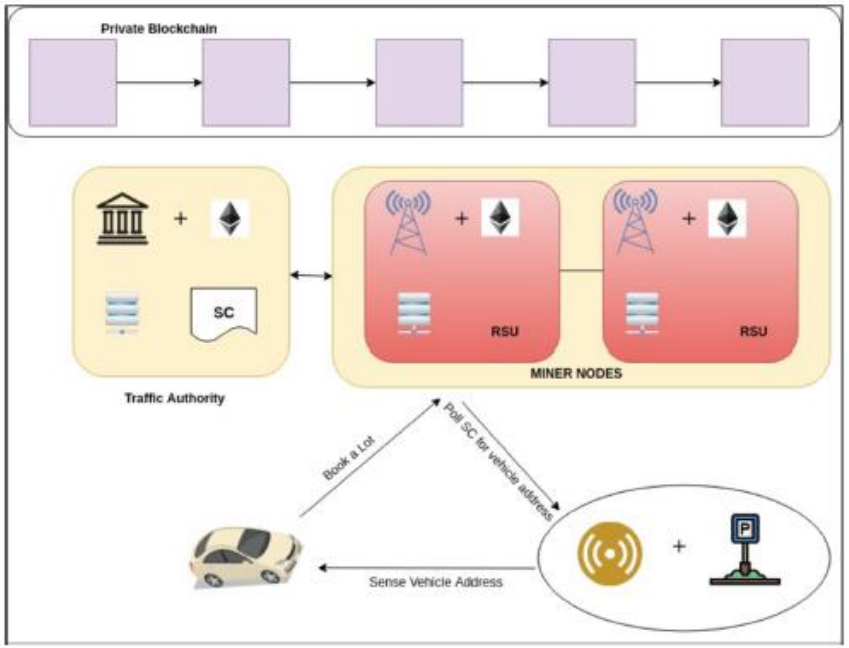

Fig. 2. Proposed system model

Use Case 2: Experimental Details

Table 1. Devices and their Role

Device name	No. of device	Geth version	Role
Dell-Vostro (8 GB RAM, i7-7700 CPU, 1 TB HDD)	1	v1.8.17-stable release	RSU/TA
Lenovo G-5080 laptop (4 GB RAM, Intel Core i5 processor, 1 TB HDD)	1	geth-linux-amd64-1.8.22	RSU
Raspberry Pi 3	1	geth 1.8.18 ARMv7	Vehicle OBU
nodeMCU	1		IoT device

Use Case 2: Testbed Setup

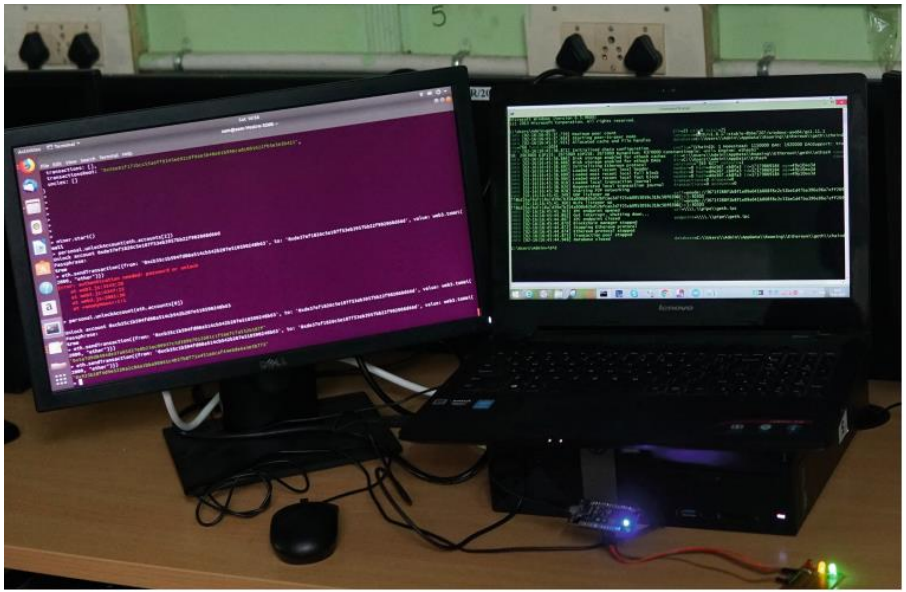

Fig. 3. Full node and miner setup

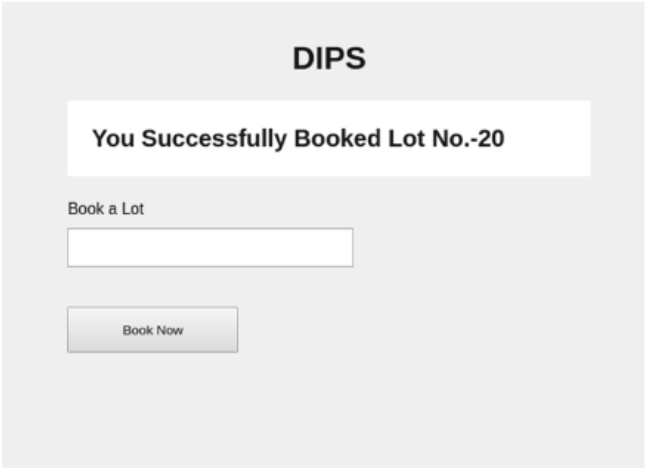

Fig. 6. GUI at the vehicle end

Use Case 3: Vehicular Insurance

Paper : A Blockchain Based Approach for Usage Based Insurance in ITS. **[4]**

Authors: Pranav Kumar Singh**, Roshan Singh**, Gwmsrang Muchahary, Mridutpal Lahon and Sukumar Nandi.

Presented At: IEEE, TENCON 2019, Kerala, India

A Blockchain-Based Approach for Usage Based Insurance and Incentive in ITS

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***Abstract*—With the increasing number of vehicles on the road, the insurance market for vehicular insurance is also increasing. There has been a massive proliferation in the number of policy taken by the drivers over the year. The traditional vehicular insurance processes used by the insurance companies rely on analyzing the history of the behaviors of the drivers for deciding the suitable premium amount to be paid by the vehicles. Usage-Based Insurance (UBI), which is based on telematics, turns out to be a modern and effective approach for providing insurance to the vehicles. Unlike the traditional approach, the premiums in the UBI are calculated based on the current behavior of the drivers. Moreover, there exists a lack of transparency in the processing of the claims, which not only results in delays of receiving the claims but also leads to a number of frauds. Decentralized technology such as blockchain turns out to be an effective solution for the problems mentioned above. In this work, we propose a blockchain-based framework for vehicular UBI and incentives in ITS. We demonstrate and analyze the feasibility of our work with proper experimental testbed setup.**

***Index Terms*—UBI, Smart Contract, Blockchain, PHYD, Proof-of-Work.**

I. Introduction

The traditional way of vehicle's premium calculation and billing mechanism are very generic, which is based on simple variables such as the cost of the vehicle and its age. However, driving behavior, maintenance of the vehicle, etc. are not considered. The existing billing mechanism is also not consistent with the individual. For example, people driving 50,000 Km per year and 10,000 Km per year pay the same premium amount. Several years of research in the areas of information and communication technologies, artificial intelligence, internet of things (IoT) and blockchain have provided a solid foundation to explore Usage-Based Insurance (UBI) as an alternative to the traditional mechanism. UBI sometimes referred as Pay-As-You-Drive is a type of vehicular insurance where the cost of the premium paid by the driver is dependent upon their driving behavior and also on their response to external factors such as speed limits, road types, congestion, etc. In 2012, there were nearly 2 million UBI based policies; however, it is expected that by 2020, the number will increase drastically to 100 million [1]. We believe that UBI will also become the key component of the Intelligent Transportation System (ITS).

The UBI-based solution offers benefits not only to insurers and customers but also to society. The customer will be benefited with a better premium payment policy. UBI employs a consistent method for premium payment, which depends upon the driving behavior of the customer. Since drivers know that their driving behavior is being monitored and they will be charged accordingly, the UBI mechanism can positively influence the driving behavior. This reduces the frequency and severity of road accidents. Drivers can feel more connected, secure, and safe. UBI can also help customers to avail value-added services such as vehicle diagnostics, emergency services, stolen vehicle recovery, etc. Efficient driving will reduce accidents, which will lower the number of claims. The insurance companies face a loss of fortune due to fraudulent claims; however, UBI allows the insurance company to track real-time driving behavior, which will enable the insurance company to generate evidence quickly. Thus, it reduces the number of false claims which in turn will minimize the revenue loss; and they can reduce the overall premium cost for their customers to make their policies more attractive. UBI facilitates customers to settle their claims more accurately and efficiently. UBI can also encourage drivers to follow a better route, avoid traffic congestion, and limit the use of vehicles, which can reduce fuel consumption and lower pollutant emissions and reduce road accidents.

To avail of all those benefits, various UBI-based solutions have been implemented across the globe, mainly in the USA, Europe, and Japan. Most of these solutions have used a smartphone-based [2]–[5] or GPS-based technology platform [1], [6] and considered only traditional telematics parameters.

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Use Case 3: Vehicular Insurance

Contribution:

Propose, implement and evaluate the Pay-How-You-Drive(PHYD) or Usage Based Insurance and Incentives

Telematics solution with Blockchain.

A Blockchain-Based Approach for Usage Based Insurance and Incentive in ITS

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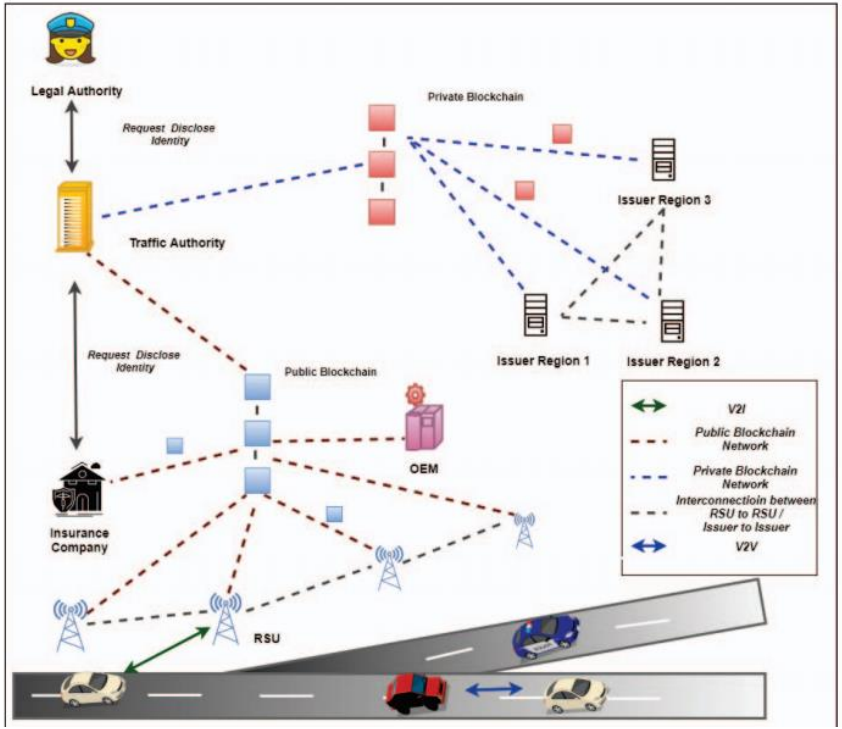
Use Case 3: Vehicular Insurance



Use Case 3: Blockchain and SC variants

Two different variants of Blockchain

- Public Blockchain
- Private Blockchain

Considered 4 different Smart Contracts

- Registration Smart Contract
- Temporary Address Smart Contract
- Issuer Smart Contract
- Policy Smart Contract

Use Case 3: Transaction Types

- Considered two different variants of Blockchain Transactions:
  - Event Triggered Transaction

$$\mathbf{ETT} = [(TID)T_s((ETT_{data})(P_{data})](Sig)$$

  - Periodic Update Transaction

$$\mathbf{PUT} = [(TID)T(_s)S_{data}](Sig)$$

Use Case 3 :Incentive Algorithm

Algorithm 1 Generic Algorithm for Incentive Reward and Premium Lease

N : Registered Vehicle (RV)
S : Set of all RV belongs to Insurance Company
F : Set of all vehicle related parameters(that should not exceed a limit such as no. of harsh brakings) determining the vehicle score
p : A parameter that belongs to F
threshold : Maximum limit of acceptance $\forall p \in F$
cutoff: Minimum score required to receive reward and premium discount.

Require: $RV_i.score \leftarrow 0$

for RV_i in S **do**
  for all p in S **do**
    if $RV_i.p \leq threshold$.p **then**
      $RV_i.score \leftarrow RV_i.score + 1$
    else
      $RV_i.score \leftarrow RV_i.score - 1$
    end if
  end for
  if $RV_i.score \geq cutoff$ **then**
    rewardCreditScore($RV_i.address, RV_i.score$)
    lowerPremium($RV_i.address$)
  else
    highPremium($RV_i.address$)
  end if
end for

Use Case 3: Experimental Setup

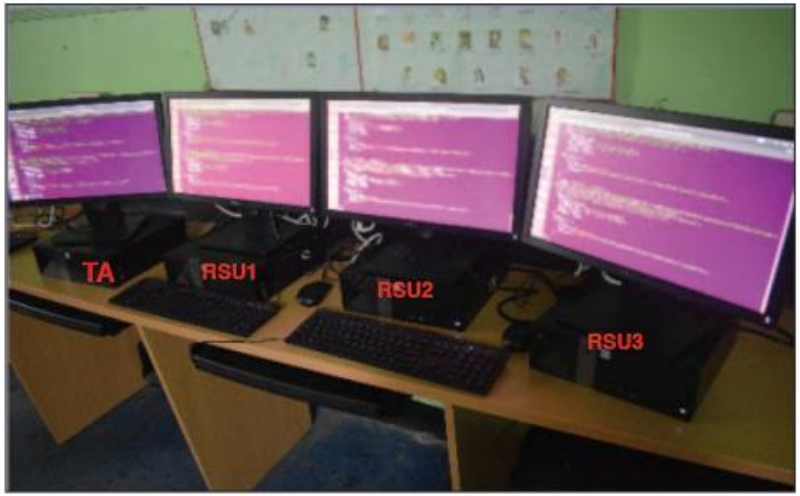


Fig. 2. Testbed Setup

TABLE I
TESTBED DETAILS

Device Name	Specifications	Role
Dell-Vostro PC	(8GB RAM, i7-7700 CPU, HDD : 1 TB, OS : 64 bit)	RSU/TA

Use Case 3: Results

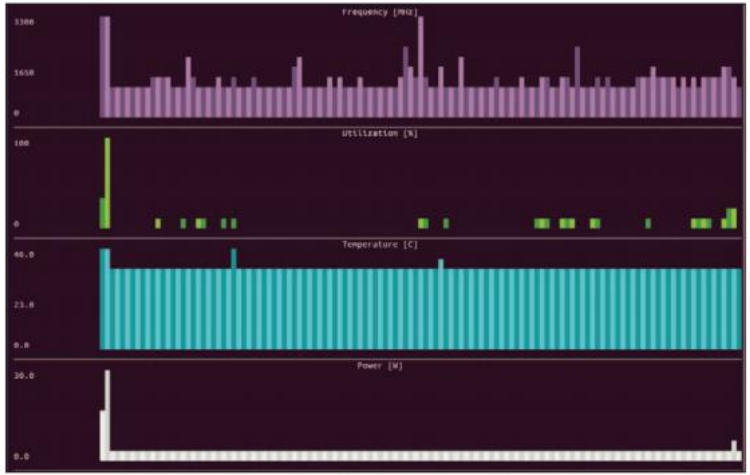


Fig. 3. Performance Plots in Idle Mode

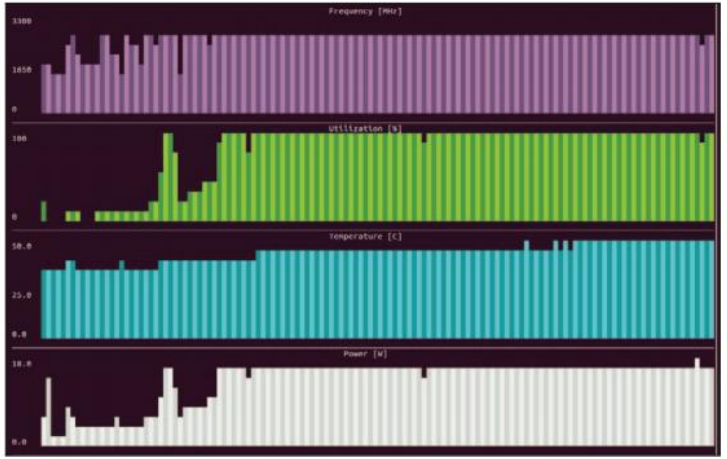


Fig. 4. Performance Plots when RSU node is mining

Use Case 3: Key Takeaways

- Power and resource exhaustive consensus mechanism can be used for maintaining the public blockchain while a voting based consensus mechanism can be considered for the private one.

Future Research Directions:

- Device Anonymization and Privacy Preservation over the blockchain.
- Designing Efficient Consensus Algorithms for IoT.
- Developing approaches for efficient data storage.

Recommended Resources:

1. Stanford Blockchain Course

2. Blockchain Architecture Design and Use Cases, *Dr. Sandip Chakraborty*, IIT Kharagpur and *Dr. Praveen Jayachandran*, IBM Research India. Link

3. Introduction to Blockchain Technology and Applications, *Prof. Sandeep K. Shukla*, IIT Kanpur Link

References:

1. Understanding the Mirai Botnet, Proceedings of 26th Usenix Security Symposium, Canada,2017. Paper Link

2. Managing Smart Home Appliances With Proof-of-Authority and Blockchain, i4CS Conference, Germany, 2019. Paper Link

3. Smart Contract Based Decentralized Parking Management in ITS, i4CS Conference, Germany, 2019 Paper Link

4. A Blockchain Based Approach for Usage Based Insurance in ITS, IEEE TENCON, India,2019. Paper Link

5. The Truth About Blockchain**,** *Harvard Business Review* Link