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Research paper

BSCL: Blockchain-Oriented SDN Controlled Cloud Based Li-Fi Communication Architecture for Smart City Network

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Abstract

The Internet of Things (IoT) smart city initiative has transformed technology spectrum into its new era of development. The increasing amount of data generated by millions of IoT devices and the rapid flow of data across distributed IoT devices are transmitting to remotely located cloud infrastructure over the Internet. Unfortunately, these large amounts of data and its flow based on the traditional energy-intensive network infrastructure is neither efficient nor substantially scalable. It is essential to design a comprehensive network infrastructure to handle large amount of high-speed data-processing in an IoT spectrum. Apparently, Blockchain and Software-Defined Networking (SDN) approaches can leveraged the scalability of the environment for IoT spectrum. In addition, the emergence of distributed cloud technology and Li-Fi spectrum can transform the capability of data-processing for IoT devices. The challenge lies in efficiently blend the integration of Li-Fi, Blockchain, SDN and Cloud technologies for IoT environment. To address this challenge, we design a multiaccess communication modulation model for efficient optimization of distributed network with an SDN based controller and integration of robust cloud infrastructure for high-speed data-processing. The proposed model is based on Li-Fi communication architecture which significantly reduced in the utilization of energy for managing large-scale infrastructure. We performed simulation and analysis across multiple dimensions to evaluate the performance and effectiveness of our proposed model. The evaluated output shows that our model significantly improved the overall performance and efficiency of the communication infrastructure as compared with other ultra-modern models.

Keywords: *Internet of Things (IoT), Light Fidelity (Li-Fi), Blockchain, Cloud Computing, Software-Defined Networking (SDN).*

1. Introduction

The emergence in the increasing number of objects which are rapidly connected to the Internet at an unprecedented rate realizing the idea of Internet of Things (IoT). A basic example of such objects includes vehicle navigation, traffic signal monitoring, high speed cameras for automatic number plate detection that enables the idea of Smart Autonomous Intelligent Transportation System. There are other domains in which the IoT can play an important role in the advancement of the technological research. These areas of application include the automation in healthcare, industry, homes, connectivity and government where decision making requires more efficiency and accuracy. The IoT can interact with the physical objects by using sensors and actuators having them think, hear and perform talk together to share information and coordinate quick decisions. The IoT transforms the physical objects from a traditional perspective to a more advance objects being integration with PV arrays, LEDs, power electronics to ubiquitous and pervasive computing, miniaturized sensors, microcomputers, sensory networks, signal processing, data analytics, Internet protocols, embedded devices, wireless communication networks such as (4G and 5G) and their applications [1].

Smart objects supported by vendors providing devices and services to specific industries with specialized requirements fall into vertical markets or domain dependent services. An example includes Simulation Software's which are related to specific industries with specialized needs to be performed according to it. On the contrary the given services and devices serve for large scale industries and customers having non-specific requirements without any specialized needs comes under horizontal markets or domain independent services. Considering a basic example of Office Productivity Suits which are classified as an open choice for numerous industries and customers having different backgrounds and its applications. As illustrated in Fig.1 which elaborates the comprehensive scenarios of IoT in which a group of domain independent services is interacting with a group of domain dependent services. Both the domains are collaborating with multiple sensors and actuators directly with each other [2].

Fig 1. Internet of things (IoT) Architecture

The changing narrative in the technological industry brings a revolution in the electronic industry which gives a wind blowing impact on the emergence of smart devices to enable smart connected vehicles, smart industry inside the smart network, smart applications in healthcare, transportation, homes and other emerging areas. In this complex scenario, the application of IoT paradigm in an urban context is an emerging trend. Since the initiative taken by many countries towards the utilization of ICT services into government domains and public affairs is largely focused on IoT ecosystem resulting into a concept of "Smart City". The major aim in this development is to make better use of public resources and improving the quality of the service to the citizens while reducing the operational cost incurred on the public administrators. An Urban IoT paradigm bring many benefits in the management and enhancement of transport, surveillance, hospital, police, municipal services and schools [3]. The large number of smart devices connected having diverse range of application with Internet in smart cities has given some major concerns related to scalability, efficiency, distribution, availability, flexibility and security in the existing smart city network.
The rising concerns for the energy crisis and the constraints in the existing radio frequency spectrum [4] on the working life of smart devices is considering to be a challenge for future. In this paper, we address this challenge and proposed a model which resolve the issue related to the efficiency and scalability in a blockchain-based architecture embedded with Light-fidelity (Li-Fi) network communication in a smart city network. We present a hybrid communication modulation scheme for optimizing distributed network performance using a proposed algorithm based on an SDN controller. We perform simulation to evaluate the effectiveness of our proposed model. The result evaluation shows the significant improvement in the performance and efficiency.

2. Emerging Technologies in Smart City Network

2.1. Internet of Things (IoT)

The IoT is expanding at a fast pace that there are predictions according to some reports [5] that it will grow up to 26 billion of devices by 2020 which are 30 times more than the estimated number of devices exists since 2009. It is also the fact that the number of smart phones, tablets and PCs used today have estimated figure of 7.3 billion which will be far more than the devices used in the future up until 2020. To reach such a massive growth, it is necessary to develop a proper strategy for managing these large number of devices. It starts from building a ground IoT stack by integrating standardize protocols and establishing proper layers for an architecture that will support the wide range of services to IoT devices. The current most existing IoT solutions mainly rely on centralized infrastructure using client-server paradigm that connects to the cloud servers through Internet. Although these solutions might work but for today's rapid advances in communication technologies, there is a need to propose new models for resolving infrastructure issues by adopting new cutting-edges technologies into the existing or new paradigms.

2.2. Blockchain Technology

Blockchain technology can track, coordinate and carry out secure transactions for storing information from a massive scale number of devices enabling the emergence of application independence from any kind of centralized intervention. It will open the new horizon of democratizing the machines by implementing various consensus mechanism for the automation process of establishing the consensus achieved from devices. It will also give cost cutting impact on the decentralization of infrastructure since most of the today's infrastructure is highly dependent of centralized intermediaries. Furthermore, it will help in reducing the concerns circulating around the tech industry related to privacy and security since blockchain have the potential to guard the network of chains from external interference while maintaining the current statues of system internally. It will eliminate the concerns related to lack of trust since closed-source code approach is transforming into an open-source approach which will be the need for future IoT solution for all domains. [6]

2.3. Software-Defined Networking (SDN)

Emergence in information and communication technologies (ICT) has reached to a significant level of importance in which every device has an integration with the Internet. This massive volume of integration gives evolution to new domains in IT industry which has higher influx on mobile networking, big data, embedded devices and connected machines. With such involvement of connected devices on Internet, there is a need to address the concerns related to existing network technologies which is now become overloaded with the flood of new emerging IoT enabled devices. Software-Defined Networking (SDN) provides a solution to overcome these challenges. SDN has ability to increase the bandwidth required by wired and wireless devices and reinforce it into existing network. It develops stricter bond with the ecosystem of IoT that provides cyberspace to every connecting object. It has the potential to intelligently route real-time traffic and bring unutilized network resource in to network utilization. [7] It will significantly increase the network performance and scalability. IoT network can benefit the emergence of Software-Defined Wireless Networking (SDWAN) technology to strengthen the controlling ability of a wireless network. With SDWAN, IoT network become more agile and scalable based on required demand.

2.4. Cloud Computing

Cloud Computing gained most of its attention to businesses as a new opportunity embedded with cutting-edge features. Larger enterprises are enjoying benefits from migration and integration of their existing enterprise infrastructure into cloud deployment. It offers an on-demand technology support for a wide range of services including Compute, AI, Machine Learning, Analytics, Business Productivity, Database, Storage, Developer Tools, Security, Identity Compliance, IoT, Management Tools, CDN, Media Services, Mobile Services, Networking, Migration and Web. Clouds have heterogenous infrastructure to provide shared resources to multi-connected peers benefiting cost and efficiency. [8] They offer flexible environment for scalable integration of various components into cloud infrastructure. The data privacy and security are a major focus on cloud infrastructure and there are many approaches currently embedded with cloud platforms supported by wide range of cloud vendors [9]. The process of standardization of cloud protocols and services is also become part of these cloud platform which ensures legal protection of all dataflow inside these cloud platforms.

2.5. Light Fidelity (Li-Fi)

The radio frequency (RF) band has introduce many wireless communication technologies including Wireless Fidelity (Wi-Fi). However, due to number of major concerns related to RF band overcrowding and safety for humans in the RF band spectrum, there is a need for the emergence in data transmission technologies. Finally, German Physicist Harald Haas proved the possible use of visible light band for data transmission in an open spectrum. Light Fidelity (Li-Fi) can transform the existing technology using RF as a signal carrier for Wi-Fi, Bluetooth and Radio Frequency identification [10]. It is an existing technology with advances in high rate of data transmission, improve safety factor and support robust security measures. Li-Fi technology is comprised of LED bulbs for illumination and data transmission. It has version of data communication systems (VLC) that leverages visible light for data transmission. It has a bandwidth range from 380nm to 750nm in an electromagnetic spectrum which initiates a frequency spectrum under the range of 430-790 THz. Since the visible light has a larger spectrum than the RF which corresponds to 10,000 times in comparison, it is conclude that VLC is better choice as compare with the RF bandwidth [11].

3. 3. BSCL PROPOSED MODEL

3.1. Overview

Based on our analysis for the existing communication network infrastructure in smart cities, there are some challenges in this regard. The current network infrastructure is inapplicable for absorbing newly emerged technologies in its spectrum. Similarly, the lack of sustainable assessment related to the issues for performance, scalability, distribution, efficiency and security fall into a major constraint for the emerging IoT ecosystem [12]. Therefore, there is a need to resolve these constraints to integrate with the evolving IoT spectrum. We propose a model based on Li-Fi communication scheme blended with SDN controllers. Our model is based on blockchain stack having support for integration with third party cloud services.

3.2. Proposed Model

Our proposed model is based on an efficient, distributed, scalable and flexible smart city architecture with the integration of cutting-edge technologies including blockchain, Cloud, Li-Fi and SDN to optimize the scalability and availability without any centralized intermediary. Fig. 2 shows an overview of proposed smart city architecture in which wide range of environments are integrated into energy-harvesting infrastructure. In data transmission over proposed smart city network, it requires some peripherals e.g. smart devices, sensors and data devices to support data transmission across the network. The overall network infrastructure is designed on top of Distributed Blockchain Network Infrastructure (DBNI) interconnected with Cloud services internally or with third-party vendors. The DBNI relates to Li-Fi enabled gateways which provides a path towards communication protocols with IEEE 802.11n standards for wireless communication. To provide efficient control over dataflow, we adopt Li-Fi communication techniques with SDN based data planes to transmit data from IoT enabled devices. In the smart city intelligent network infrastructure, all the controllers are interconnected with distributed network architecture. It will support high-end communication with shorter response time.

3.3. Communication Scheme

In our proposed model, we adopt Li-Fi communication technique as shown Fig. 2, the general overview of Li-Fi communication between smart devices and controllers. When the smart devices request for communication with SDN based controllers, it diverts towards encrypting the data using encryption technique named Dynamic Secret-based Encryption (DSE) scheme. After passing through this process, the device will send the encrypted data to modulation block for creation and modulation of data frames. It will create and encode the data frame and pass through modulation process. On the completion of this process, the LED array frame block emits LED rays to communicate with the controller integrated with a photodetector for receiving data from smart devices. Similarly, for the demodulation process the decoding of data frames passes through the decryption block to recover data transmitted from the controller. This process continues similarly for both the sending and receiving operations. To enable bidirectional communication between both ends, we proposed a hybrid communication model scheme. We also consider a multiaccess transmission support for VLC using mobile phones as proposed.

a. Dynamic Secret-Based Encryption (DSE)

It is wireless network encryption technique designed to secure the communication between smart devices and the control planes [13]. The basic idea of DSE is to develop a shared symmetric secret key using transmission errors and legitimize users dynamically. The monitoring of error retransmission is monitored by both the sender and receiver in link layer. This process is to quantify the group of frames synchronously and hashed into dynamic secret to encrypt data. The deployment of DSE is to optimize the wireless communication in smart grid.

b. Hybrid Modulation Scheme

The hybrid modulation for Li-Fi comprised of Code Division Multiple Access (CDMA) and Color-shift Keying (CSK) schemes respectively. The CDMA has capacity for enabling multiaccess while the CSK helps to avoid single-color interference [14]. It enhances the L-Fi capacity to access network more efficiently. Each smart device will equip with self-modulation and magnitude levels using orthogonal spreading-code technique.

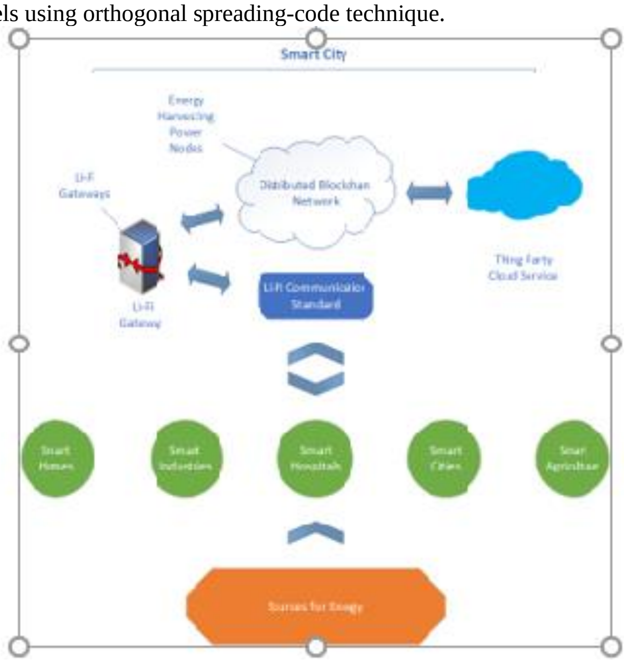

Fig. 2. BSCL Distributed Blockchain Network Proposed Model

3.4. Network Infrastructure

The comprehensive proposed model is based on blockchain network infrastructure for achieving efficiency and scalability with all IoT-enabled devices with supported SDN controllers in a distributed topology in smart city network. Each controller is implemented SDN based FS-OpenSecurity model [15]. The FS-OpenSecurity model supports strict network security measures to optimize the overhead caused on SDN controllers with the help of rifting between control and monitoring functions. It will help in better network management based on dedicated policies, support more agile practices and increased in more automation with the overall simplified architecture design. By using blockchain Proof of Work (PoW) mining algorithm, we proposed that all the SDN controllers in the chain will be miners and there will be the pool of miners for mining process. Furthermore, there will be the integration of relevant SDN controllers depending on the results from the accurate analytical intelligence.

3.5. Optimization Algorithm

Algorithm 1 : MPC

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Input: M(t), C(t), G_avg, σ, MinerList[], ControllerList[], Timestamp[], SDNcontroller[], indX = 0, indexY = 0
Output: Best Fit Selected Miner M_i
Begin:
    For each Miner M_i and Controller C_i , i → n do
        If M_i > G_avg then
            MinerList [indX] ← M_i
            SDNcontroller [indX] ← σ_i
        Else
            Timestamp [indexY] ← M_i
            ControllerList [indexY] ← σ_i
End
```

Fig. 3. Mining Performance Controller Algorithm

4.2. Network Defense Evaluation for Security Measure

In this analysis, we evaluate the security measures of each SDN controllers during isolation attack on distributed blockchain network model. We configured two queues simultaneously, one directly from switch to controller and the second from controller to switch for communication. The configuration for the transfer of User Datagram Protocol (UDP) flood attack, we setup client as an attacker and resume other clients to communicate normally with each other. To evaluate the impact of attack on the rates of the network bandwidth, we perform our proposed model with other SDN controllers in the given environment. To control any unexpected disruption, each controller passes through at a time to avoid any collision. The SDN controller's bandwidth started to decrease gradually as the attack rate on packets per second increased rapidly in the environment. However, as the rate of attack increases to maximum then the OpenFlow switch started to become malfunction since the failure of managing the buffer overflow and weakness in the mechanism for controlling the attack by using optimization to monitor the flow respectively. On the contrary, as shown in Fig. 5 the proposed model efficiently handles this malfunctioning and shows comprehensive performance compared with the bandwidth for other methods.

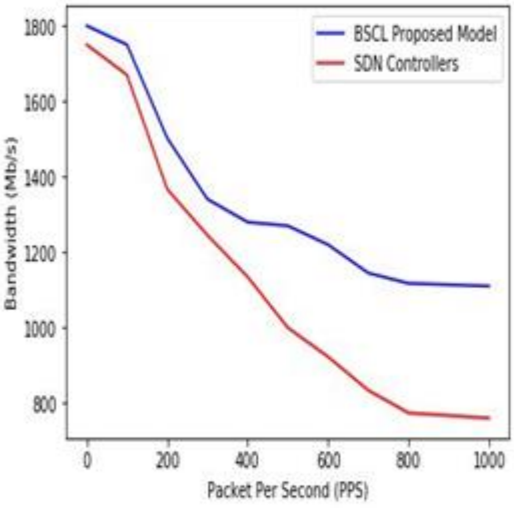

Fig. 5. Bandwidth result by the using Mining Performance Controller (MPC) Algorithm

4. Conclusion

In this paper, we proposed an efficient, robust, scalable and distributed smart city network architecture based on Li-Fi communication technique and IEEE wireless standards. This model will serve as the emerging requirements for the sustainability of the smart city network infrastructure. The rapid increase in the growing number of IoT enable devices and their application can benefit with this model which has the characteristics of integrating into IoT infrastructure. It also has the capacity to manage large-scale IoT enable devices encompasses into its spectrum. Similarly, we also proposed a controller algorithm for handling the performance constraints in the distributed blockchain network infrastructure for smart city network. The overall evaluation shows that the proposed model works more effective with our proposed controlling algorithm resulting in significantly reduce in the response time and delay tolerance overhead on the overall network which gradually improve the performance of our proposed model. Furthermore, our proposed work concerns mostly on the diverse issues focusing on an inherent challenge in smart city network. It is mostly persistent towards the area of SDN concerning the deployment of SDN nodes into distributed network infrastructure. This persistent issue is in the process of research and further development is in continuing stage in this area. Our research will contribute to find the possible solution for addressing these challenges and taking account for future advancement.

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