Blockchain and Fog Based Architecture

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Fog computing (FC) is used to reduce the energy consumption and latency for the heterogeneous communication approaches in the smart cities' applications of the Internet of Everything (IoE). Fog computing nodes are connected through wired or wireless medium. The goal of smart city applications is to develop the transaction relationship of real-time response applications. There are various frameworks in real-world to support the IoE in smart-cities but they face the issues like security, platform Independence, multi-application assistance, and resource management. This article is motivated from the Blockchain and Fog computing technologies and presents a secured architecture Blockchain and Fog-based Architecture Network (BFAN) for IoE applications in the smart cities. The proposed architecture secures sensitive data with encryption, authentication, and Blockchain. It assists the System-developers and Architects to deploy the applications in smart city paradigm. The goal of the proposed architecture is to reduce the latency and energy, and ensure improved security features through Blockchain technology. The simulation results demonstrate that the proposed architecture performs better than the existing frameworks for smart-cities.

Keywords: Fog computing ; Blockchain ; Internet of Everything (IoE) ; Smart city ; security ; BFAN

1. Smart City

The origin of smart city stems from the improvement in the quality of life of citizens and optimal resource utilization of the city [1], due to the recent acceleration in the urban living. The improvement in infrastructure and services has upgraded the quality of life. This has been possible due to the Internet, communication and information technology advancements [2]. Some of the expectations derived from the idea of smart cities include efficient public services, and better infrastructure, which is easily accessible and more interactive. The smart city vision has become a reality with the potential of the Internet of things (IoT). As a consequence, the smart city has come out as one of the major drivers for the IoT applications. The entire city is covered with the physical objects, which are interrelated with the IoT system. The four pillars that can be connected with IoT concepts are data, things, people, and processes. The Internet of Everything (IoE) emerged with the people in the IoT paradigm, whereby an interconnected network is aggregated in IoE. Therefore, the vision of a smart city integrated with IoE pillars to facilitate promising services in the future.

2. Development

The distributed environment used for the IoE's generation of Big Data (BD) has the potential to raise the problems of data storage and data processing. Cloud computing can be a solution; the processing and storage can be acquired on-demand, based on a pay-as-you-go manner. However, inherent problems are the reason for the inefficient working of the applications in the cloud environment [3]. For example, the traffic monitoring and health monitoring application in the smart cities cannot afford the delay in communication from the origin of data to the cloud data center, and then again, at the end-point application. Therefore, the fog computing concept has emerged recently. It reduces the network traffic and processing time of data by bringing end-user closer to the cloud services at the edge of the network [4].

Cisco [5] has given the FC's primary definition as "Fog Computing is a paradigm that extends Cloud computing and services to the edge of the network." The Fog Node (FN) helps in the execution of IoT application, which is one of the basic fundamental entities in FC. Generally, the FC acts as an intermediate layer between cloud infrastructure and end devices/end users. IoT applications need low latency, geo-distribution, awareness, and mobility support. The proposed BFAN architecture is aimed at improving the mentioned param by processing most of the data near to the end-users or end-devices. The security is enhanced with the Blockchain technology. Blockchain is a chain of blocks that grows with each transaction and is linked through cryptography. The block is a combination of transaction data, timestamp, and previous blocks' cryptographic hash.

It is a new buzzword that is capable of attracting many developers and researchers. Blockchain helps to provide true redundancy and full decentralization. The smart contract resource allocation algorithm helps to provide the on-demand resources and, bills are generated after the usage. The key is managed by the user and fragment stores in the encrypted

format. There is no third party involved in controlling and accessing data. Therefore, there is no way to recover the lost private keys.
The monitoring of resource utilization helps in comparing the value of performance metrics in service level agreement (SLA) with real-time values. This helps to provide the quality of service (QoS) to the end-user. The storage cost of Amazon S3 is $25 per TB/month, where Blockchain's cost is approximately $2 per TB/month [6]. Thus, the blockchain has the potential to reduce the storage cost by up to 80%.

The FNs can be chosen as the nearest medium for processing and storage, which can reduce the delay of data transfer at a remote location as well as save energy. The proposed BFAN framework attempts to answer various issues such as:

- Security: The security in the smart-cities concerned with cyber-security and physical security. In this article, the protection of data from attacks, computing infrastructure, and network are performed using Blockchain technology.
- Caching: Low-latency is one of the vital aspects of smart-city. To achieve this, caching is used to store more frequent data at different locations in a network. Caching also helps to reduce network congestion by avoiding the flow of repeated data on the network. Fog computing with caching enables a variety of applications in smart cities.
- Scalability: This enables elastic services in Fog computing in order to provide the Quality of Service (QoS). Dew computing concepts is applied in the proposed BFAN architecture to provide a fast and scalable cloud-like environment near to the IoE devices.
- Sustainability: The energy-efficient frameworks is the current requirement for smart cities using renewable energy sources. The sustainability aim is to reduce carbon footprints. Nowadays, brown sources produce more than 80% of the energy used in data-centers [7][8]. Therefore, we consider sustainability as a major concern in the article. The proposed BFAN framework helps to reduce the carbon footprint, increase the profit and hardware reliability.
- Context-awareness: An ability to obtains the node locations and information of the environment is called context-awareness. The proposed BFAN framework is context-aware and considers the environment param and node locations to choose the appropriate mode of communication. This add more meaning to the current state-of-the-art for energy efficiency and services of smart cities.

It is important that the components and services in the smart cities must be equipped with emerging technologies of 4 pillars. The major contributions of the article are listed below:

- We have devised a smart city architecture with Blockchain and Fog Computing for every device.
- The resource provisioning model has been presented for FN-to-FN, devices-to-FN and device-devices components.
- The real dataset has been used to evaluate the performance of our proposed BFAN model in various types of communication.

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