A Survey on Emerging Software-Defined Networking and Blockchain in Smart Health Care

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Abstract. With assistance from Software Defined Networking (SDN) and Blockchain, networks have become more creative to build and maintain over the last few years. The inflexibility of modern network architecture is presenting researchers with a tough achievement. SDN replaces existing inescapable and complicated networks with a creative way of separating the control plane from the data plane and fixing those constraints, namely configurations done manually, monitoring, protection, usability, and functionality. This paper provides an overview of blockchain and SDN in healthcare. Various existing projects of their integration have been studied the benefits of the Blockchain provides security, privacy, integrity to the health care data has been discussed. The decentralization feature of blockchain provides access to data within and across the nation. Different use cases are discussed in the paper that provides the acceptability of blockchain and SDN in healthcare. This paper provides the overview and results that integration of blockchain and SDN in healthcare is a good research area and various initiatives have been taken to explore its integration.

Keywords: Software Defined Networking (SDN), Blockchain, Architecture of SDN-Blockchain, HealthCare, Use Cases.

1. Introduction
All Sensor networks are inherently application-specific, and can not be flexibly configured. Software-defined networking (SDN), fortunately, will financially increase the flexibility and agility of the sensor networks. SDN is also defined as Software-Defined Access (SDA) is the disintegrating the data plane and control plane. allows more flexible network management by dividing the control and data planes [1]. Throughout the light of such an advantage, SDN has indeed been strengthened to the wireless mobile access network and 5G. Software-Defined Networking (SDN) is an evolving approach progressively embraced to promote and automate network infrastructure and configuration, gaining enormous support from industries and universities. To avoid, track, monitor, segregate, reduce, and likely reduce the adverse effects of most network intrusions, it is indeed a comparatively new platform to establish infrastructures that facilitate a more complex model by bringing reliability and security toward the front of the process [2]. The primary aspect that has enhanced the technological innovation in the SDN architecture is the centralization of the control plane, which is dispersed in the routers and switches inside the conventional networks with forwarding devices functionality. Although SDN is more protected against certain threats and offers network management tools that are flexible and extensible,
it poses new vulnerabilities that do not exist in conventional networks [3]. In SDN multiple threats include switches vulnerabilities, interaction in the control plane, etc which achieves the secure and robust environment in the network. SDN architecture includes a layer at the bottom, mid, and top. The bottom layer is the infrastructure layer that maintains network forwarding facilities; the middle layer is the control layer that specifies the layer of infrastructure, and the top layer is the application layer that delivers data traffic to the control layer [4]. In particular, OpenFlow is the most famous and popular protocol of SDN and it separates the control logic from forwarding data. It was developed by Stanford University and it is now transformed by the Open Network Foundation (ONF). It is most widely used in larger networks like GENI and JGN-X. It is the intermediate between dumb devices and controllers in SDN, and these dumb devices are known as forwarding data, and controllers are known as control logic. This protocol is mainly used for ethernet networks [5]. The OpenFlow Controllers determine what and which actions are to be targeted by the switch. There are various benefits of SDN are:

(i) Control functions in the network are programmable directly as forwarding functions are disintegrated from the control functions.
(ii) Simplifying forwarding control helps administrators change the network-wide traffic flow continuously to satisfy varying demands.
(iii) SDN allows network administrators to more easily customize, control, protect, and optimize network resources through flexible, programmed SDN software, which they can code themselves since these programmers are not proprietary software-dependent.
(iv) SDN simplifies system development and execution when introduced by open standards, as information was given by SDN controllers rather than numerous, vendor-specific communication protocols.

To highlight, SDN splits the system into many different planes, enabling IT to influence their network efficiently based on what tasks they need to execute. Figure 1 indicates the architecture of SDN and Blockchain by putting in the various blocks of data to the SDN architecture to overcome the issues of a single point of failure (SPOF) [6]. The application and control planes are thereby used to enhance the security feature to facilitate the protection. Therefore, the use of technology named "blockchain" will enable us to increase the security of the centralized controllers and multiple networking devices in the forwarding plane.
Blockchain technology provides one of the new tools which we need to secure data from cyber attackers, predict potential fraud, and reduce the possibility of stolen or corrupted data. Innovative technologies of blockchain can be particularly useful for enhancing cybersecurity. Blockchain provides the concept of immutability as blocks are linked to each other using a cryptographic hash which further does not need any involvement of a third party. The first block of the blockchain is known as the genesis block as it does not contain a hash of the previous block [7]. Various fields of the block are timestamp, nonce, data, previous hash, and a hash of the current block. Blockchain uses consensus algorithms for the generation of the block and makes it tamper-proof. Peer to peer networking is done to verify the transactions and the addition of these transactions in blockchain takes place after the successful completion of the consensus algorithm. Different consensus mechanisms in blockchain are Proof of Work (PoW), Proof of Stake (PoS), Proof of Capacity (PoC), Proof of Elapsed Time (PoET), etc. Distribution of blockchain ledger is done on each participating node [8]. Various benefits of blockchain are anonymity, privacy, immutability, security, and data integrity [9]. Figure 2 shows the fields of the block and how they are linked together in a blockchain. These benefits make blockchain compatible with various platforms. Blockchain has gained a lot of acceptance because it can be used in a variety of use-cases with a wide range of applications. It provides security to transactions of events through trust, privacy, consensus, and smart contracts [10].

The following characteristics of blockchain increase its wider acceptability:

(i) **Immutable and Efficient:** Adding transactions to the blockchain makes it more efficient as there is a need for a third party (like a bank) for its verification process. Once transactions are verified and agreed upon by the participants of the blockchain, then they are added to the blockchain and cannot be altered.

(ii) **Decentralized:** It is the technique if distributing and dispersing off the powers from the central authority. Here, information is not stored at a single location rather it is stored in different data servers which are part of the network.

(iii) **Secure:** Every user has keys to store the fragment of data in encrypted form, which provides complete privacy to the data and that too without the involvement of a third party. Data is stored linearly and chronologically, so each node contains a hash of its block along with the hash of the block preceding it.

(iv) **Pseudonymous Identity:** Pseudonymous identity means who is the owner of the data is not known to anyone on the blockchain but transactions created by users are visible to all.

(v) **Openness:** This technology is open-source and is available to everyone with the data. Its data can be queried by anyone, one can build applications via open interfaces.

(vi) **Auditable:** As each of the blockchain transactions is authenticated and documented with a timestamp, blockchain users can very easily identify previous records by accessing any node throughout the distributed network. This feature makes the data traceable and transparent in the blockchain.

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Figure 2. Blockchain

2. Background

2.1. Blockchain and SDN in healthcare

As per a report, by 2019 about 45 percent to 60 percent of all existing networking investments would be raised on SDN, creating it a suitable demand of $5.4 billion for less than three years. There are many
factors why SDN is motivated to deliver well in the IT healthcare industry [11], in particular about Observation of patient, data protection, and efficient communication.

- **Patient Observation:** Observation of the patient needs an effective scalable, flexible, secure tracking system that requires to have patient information given anywhere an assisted living in a hospital. Patient observation is permitted to look forward to the patients as they shift from one place to another. Besides, to build a network loop, a wire can be plugged into an accessible port [12]. Contemporaneous endpoints of patient observation endorse both wired and wireless functionality and safe monitoring device controller connectivity as it varies between wired and wireless connections. When a patient tracking endpoint enters the network an SDN controller identifies it. In general, the system switches transfer and forward information, enabling the endpoint to directly communicate with the controller for monitoring patients. The network monitored can link any position within the network of SDN switches. The SDN controller defines the endpoint and activates the Virtual Network Interface.

- **Data Protection:** Patients will have to pen their medical records until the modern period. Fortunately, mostly with the development of modern medical records, physicians can obtain the medical data of a patient directly to administer drugs and check the test results. While electronic records bring numerous advantages both for physicians and patients, safety concerns were posed [4]-[13]. In particular with the increase of cyber threats, patient records must be stored confidential. SDN can offer the requisite protection and versatility to move patient information from one end-point to another. SDN controller technology can build virtual networks for health-related web technologies, and install security systems customized to every system. Besides, Neelam Hospital has been allowed for using SDN to install 4 distinct virtual networks over a single network connection. The hospital promised to maintain the tabs on patients diagnosed by increasing its 3G network.

- **Efficient Communication:** Speech and visual contact are essential to health care. They encourage doctors to conduct video conferencing in patient homes, reducing unnecessary hours in waiting areas. This is especially useful for patients residing in rural communities who are unable to flee their homes for any cause. Medical facilities with that kind of technology reach further than the walls of hospitals [14]. Healthcare professionals need continuous and efficient communication and adequate Quality of Service (QoS) to deliver such facilities. Static voice call implementations can function well for wired and wireless mobiles. SDN helps the efficient communication controller to notify the video or voice call network which is configured for the call itself.
It has been predicted in Figure 3 that frameworks of healthcare will be rising in the year 2020 because it collaborated with the blockchain and many other technologies like Artificial Intelligence, Internet of Things. Various stakeholders like NGOs, Clinics, Laboratories, hospitals, pharmaceutical companies, supply chain management, etc. will be benefited through its collaboration. Healthcare is an important process to store and manage the medical record of patients. This process provides better care, well-managed tracking of diseases and its cause, medical record for research purposes, etc. Hospitals are mainly responsible for generating this data. It becomes very difficult for healthcare professionals to diagnose the disease and sometimes the repetition of a laboratory test is also done which becomes very difficult for patients. Various client-server or cloud-based management of healthcare data is prone to data fragmentation, security and privacy, and system vulnerability. Blockchain technologies have been used for providing access to medical records of the patients among different stakeholders. Various healthcare and blockchain-related projects are Blockcypher, Hashed Health, Guardtime, Bitmark, Medibloc, Carechain, Enigma, doc.ai, etc. MedRec model has been proposed for managing data of electronic medical records [1]. MedRec incorporates blockchain properties that provide authenticity, confidentiality, accountability, and data sharing insecure manner. Support of blockchain in IT healthcare and its benefits are:

(i) **Guarantees the Privacy:** Providing privacy to the patient’s record is of utmost importance as healthcare data is very sensitive data. The digital data record of the patient is shared with the required stakeholders.

(ii) **Secures the Health Data:** Data integrity of the confidential data is maintained as data that resides in the blocks cannot be tampered or misused by any unauthorized person. The
integrity of the data is very essential as wrong data can lead to an incorrect diagnosis. Data is decentralized due to which it can be accessed locally or internationally.

(iii) **Data Replication**: Replication of the data at different participant nodes provides highly consistent and highly available data. Latency and throughput are performance parameters that affect data replication strategies.

(iv) **Smart Contracts in Healthcare**: Smart contracts can provide access to correct data to the right person at the desired time. Proper rules and regulations will be followed to access the data. This also ensures that the data will not be misused by any organization or stakeholders.

### 2.2 Literature Studied

In reference [13] authors have explained the SDN based on data chain that is proposed based on blockchain which provided consistent data record management of SDN and also manages the fault recovery of the multi-vendor device. It minimizes the expenditure of failure of the network and accomplishes the capabilities of business in the unified scheduling. In reference [10] authors described the framework for the development of blockchain in SDN for the centralized environment of the network. This paper facilitates the challenges and its possible solutions for the integration of blockchain and SDN. The authors in reference [7] have surveyed various applications of blockchain in healthcare and recognized multiple research opportunities in this paper. Authors claimed that the ownership of the patient's data will be possessed by the patient only with the help of blockchain-Supply Chain Management (SCM) to improve the clinical trials of visibility of data. In reference [15] Switches of SDN are configured by the PDA to emulate the functionality of SDN with Mininet. To confirm the WBAN’s for reducing the deployment and network complexity results in effectively connected devices and the connections amongst them. In reference [4] authors have covered major considerations of blockchain for facilitating security and protection to the framework of SDN. Integrity, Confidentiality, and accessing the networks’ infrastructure can be accomplished by the integration of SDN with blockchain. In reference [8] lightweight blockchain model is proposed to minimize the complexity of the bitcoin network by forming clusters of network participants and keeping only one ledger per cluster. Forking of the blockchain is also avoided in this network. To achieve the scalability, and energy-efficient consensus mechanism is established which made the system faster. The authors of reference [16] have applied the blockchain technique in PSN healthcare and secured healthcare data is stored in the blockchain. Secure links are created for the intensive computation of mobile devices and sensor nodes with limited resources. In reference [12] authors have made the comparative analysis of IoT and blockchain in healthcare which implements the challenges and their defined solutions for both academia and industry. This paper analyses the various aspects of the adoption of the technology of blockchain in the consensus protocol and applications.

### 3. Use cases of Blockchain in SDN

In today’s modern technology such as Cloud computing, the Internet of Things (IoT), etc. networking is getting more complicated. Offering a sufficient bandwidth in real-time, stable communication could be a hurdle [17]. That’s also especially important in healthcare, where safety, enforcement, and patient safety all improve the deepness of data transfer privacy and scalability. This is why most healthcare institutions are investigating SDN solutions together with blockchain in health information technology.

(i) **Network Traffic prioritization**: In a context where the efficiency of a network can affect a patient’s life or mortality, healthcare institutions must have significant exposure to network facilities that emphasize intelligent traffic. In [18] the network, for example, claims to be able to realize the difference between a doctor who accesses documents for an annual checkup or one who accesses the others for immediate surgery. The use of SDN in health IT helps to ensure that low-priority traffic, including such back-office software or an
executive watching YouTube in the hospital canteen, rarely takes precedence over transmitting hospital documents to anyone in an emergency room.

(ii) **Lowering Failure Occurrences:** These are some of the main advantages of using SDN has been its automated configuration of packets to different routes to enhance network management. In a [9] conventional network configuration, infrastructure procurement is among the IT’s most time-consuming fields.

(iii) **Changes in track configuration:** If a change occurred dynamically or by a system administrator, improvements to the configuration can easily be detected via SDN. If in case of a mistake, preventive maintenance is required, the actions may be more concentrated since there is a log of each adjustment.

(iv) **Suitable for mergers and acquisitions:** In ancient times, several problems have been generated by integrating a new acquisition or merger into the current Network. With SDN in [16] health IT introduces limit-touch procurement it takes a couple of times to introduce a different site into the network.

(v) **Data Sharing:** Data sharing is very important in healthcare to remove unwanted repetition of the laboratory tests [19]. This healthcare data can also be used for research purposes as it can be collected from different demographics, diagnoses, and medical history.

(vi) **Personal Identity:** Personal identity of the patient is maintained in the healthcare records. Personal identity is preserved within data that provide accuracy, consistency to the data [15]. The decentralized nature of blockchain makes the data universal. A healthcare facility is available within and outside the nation’s boundaries.

(vii) **Maintenance of Personal Health Records:** Patients can easily combine their medical records. Patient’s immunization records, prescription records, doctor’s visit data, data aggregated from smart healthcare devices can be easily maintained in the blockchain ledger.

(viii) **Insurance Claim:** Health insurance can be claimed by the person in case of a major accident, chronic disease, or medical emergency [20]. Records of the health insurance payment and its claim can be maintained by the insurance companies by incorporating blockchain in record maintenance.

(ix) **Auditing:** Auditability of the data is ensured. Validators of the blockchain network confirm the auditing of the pharmaceutical records, prescription records in a convenient way

4. Results and Discussion

To improve the accessibility and reliability of services, Wi-Fi networks are widely used in the healthcare industry. The drawback to this immense-scale development is the underlying issues that are heightened due to the rise in wireless devices and the spontaneous implementation of APs. To achieve an optimum load balancing state, a variety of repeated connections are required. The load balancing decisions are made either by changing the APs’ network coverage or by regulating the process of connection regulation. Due to non-standardized regulations and hardware, the load balancing tasks in conventional Wi-Fi networks are difficult to accomplish.

SDN is a new methodology which, by distinguishing the control plane from the data plane, serves as a means of organizing network functions. In the management of the network and control tasks, this separation offers simplicity. A centralized view of the entire network enables intelligent forwarding
decisions to be made by the SDN controller. Rather than depending on hardware customized and designs of protocol, we assume that the combination of SDN and Wi-Fi i.e. software-defined Wi-Fi networks (SD-Wi-Fi), will produce better load balancing techniques. In this section, we have discussed the traffic-aware load balancing technique in healthcare.

Figure 4. Application of SDN and Blockchain in healthcare

Smart devices are mostly used to access the health information, many doctors can use that information but security and privacy is a major issue in data being released by smart devices. Authentication, sharing of data, security, data integrity, data storage, confidentiality and mobility of records of medical data are the major constraints for the healthcare industry. Data generated by such devices need to be secured by blockchain. Gem health network, OmniPHR, Pervasive Social Network system, Medshare, Healthcare Data Gateway are few applications of healthcare that are existing using the blockchain Technology. In Figure 4 The system architecture comprises a centralized controller, APs, an web servers, and Wi-Fi stations activated by OpenFlow. On obtaining the status reports of AP’s, the controller measures the fairness index of the Jain and computes the average load age for wise decisions on balancing the load. The server based on Application hosts a range of other servers, comprised of file servers, multimedia servers, servers for web applications, etc. These servers acknowledge to requests from users on the Wi-Fi network. Balancing the load and applications based on traffic-awareness running on the SDN controller guarantee that even the distribution of load amongst the AP’S is accomplished and the traffic that is delay-sensitive such as an electrocardiogram is assigned high priority.

5. Conclusion
This paper provides an overview of blockchain and SDN in healthcare. Various existing projects of their integration have been studied and discussed the benefits of the Blockchain that provides security, privacy, integrity to the health care data. The decentralization feature of blockchain provides access to data within and across the nation. Different use cases discussed in the paper provides the acceptability
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