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ORIGINAL ARTICLE

Managing Internet of Things Based Traffic Using Software Defined Networking

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ABSTRACT

The current internet architecture cannot manage the massive data volumes produced by the smart IoT-based healthcare systems. Very recently, the idea of Software-Defined Networking (SDN) has surfaced to resolve the issues related to networking. The incorporation SDN technology in IoT-based healthcare system can possibly solve the existing quality of service and data management issues. Furthermore, the IoT-based healthcare system can attain enhanced Quality of Service (QoS) through the employment of such schemes that use shortest-path routing algorithms and offer higher bandwidth to lesser delay paths as per the QoS requirements. In this study, the SDN technology is integrated with IoT-based healthcare systems and the delay is reduced for delay-sensitive applications by using the Bellman-Ford algorithm. The proposed scheme is deployed using the POX controller and can effectively handle the existing QoS issues in the IoT healthcare systems. The simulation results of the proposed scheme show a clear drop in delay values in comparison to the benchmark scheme.

Keywords: Software Defined Networking (SDN), Internet of Things (IoT), Quality of Service (QoS)

Author`s Contribution	Address of Correspondence	Article info.
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INTRODUCTION

IoT is a network of smart devices and objects. The physical identities and attributes of smart devices provide functionality so that using standard communication protocols they can self-configure [1]. In IoT, smart devices generate bulk of traffic using heterogeneous networks [2]. In IoT based smart healthcare system, the patient's disease is diagnosed by installing biosensors on patient's body. The patient's reports can be shared online with doctors for advice. Wireless body area network (WBAN) is mostly used in smart healthcare systems. An important feature of the network is QoS that is required essentially. Depending upon the nature of the application, it can be defined to opt for the paths in a network. The important parameters include throughput, packet loss and delay. Each network has its own application dependent prerequisite, and presently the internet architecture cannot deal with the real-time data generated from different networks. IoT accomplish results in congestion so in the current network QoS cannot be provided for real-time data. Thus, for achieving QoS, a new communication architecture is desired [1].

Smart devices can be connected through the internet. This will create a large amount of traffic which cannot be handled with conventional network. For smart healthcare and grid applications, real-time IoT analytics requires QoS to be achieved. By doing so, SDN can play an important role in managing the IoT data for real-time analytics [4].

Smart healthcare system based on IoT plays a vital role in the medical field. In smart healthcare architecture, data is generated through WBAN sensors implanted on the human body. The IoT gateway will use any communication protocol to forward the data to the cloud [4]. A solution is suggested for delay-sensitive application but it was observed that due to TCP protocols three-way handshake mechanism, latency is created in the network [9][10].

The researchers in [3] proposed a novel authentication scheme to prevent multiple attacks in SDN-based IoT network. In [5], the authors applied cloud based SDN technology to build a smart health care system. In [6], authors proposed an efficient switch migration-based load balancing for multicontroller SDN in IoT. In [7], researchers proposed an architecture which aims to structure a distributed security measure integrating firewall, IPS, switches and a controller entity to support Internet of Things (IoT) instances, allowing the identification of anomalous behavior of IoT devices by the IPS, thus leading the SDN to block the attacks as near as possible to the sources. In [8], the authors presented a composite architecture named SD-IoAV for the integration of SDN with IoAV.

In the field of smart healthcare, one major problem is achieving QoS and data supervision. The data can have different applications that depend upon QoS [4]. Each application requires network support to achieve QoS.

This problem can be resolved using SDN which has a linking architecture that separates the data plane and control plane. Instead of programming the control plane manually in the data plane, SDN makes the network functionality simple by programming the control plane in a centralized manner [2]. Thus, by using SDN communication model, QoS problem in IoT can be resolved. Bellman-Ford algorithm is used to achieve less delay in a directed graph. The paper is organized as follows. Section 2 provides literature review of SDN and QoS using SDN. Section 3 provides description of methodology and system model implemented for achieving QoS using SDN. Section 4 provides results and its comparison with benchmark results in [17]. Section 5 provides conclusion and the future research directions.

LITERATURE REVIEW

a. Software Defined Networking (SDN)

Software Defined Networking (SDN) [32] which is an evolving network architecture [33], is a viable candidate for addressing current network issues and challenges. SDN resolves various issues and problem in the network.

1. Separating a control plane from the data plane, SDN breaks vertical integration in conventional networks.
2. Breakdown of the data plane and control plane identify the outcomes in the conversion of switches of network into forwarding device in the simple packet and the implementation of a control plane using a central network controller. This approach results in simplifying policy on network implementation by the operator of network and helps in the process of network configuration and development [34]. Figure 1 shows a simplified SDN architecture.

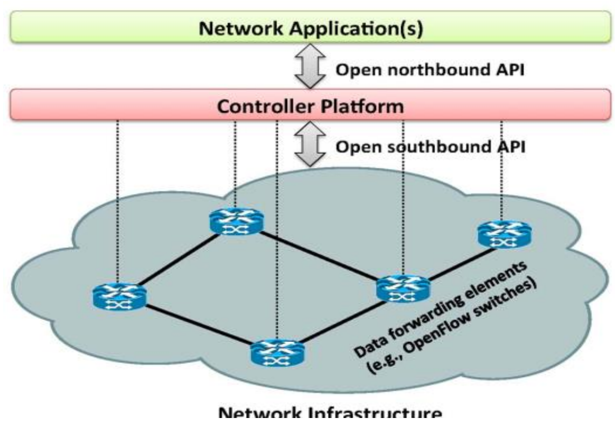

Figure 1: SDN Simple architecture

Logically centralized does not mean that the control unit is a physical centralized system [35]. Interconnectivity between the switches and the SDN controller creates a breakdown of the data and control plane can be grasped by a well-definite programming.

In [11], the authors proposed an open-source SDN solution for the IoT, bringing the following novelties in contrast to the related works: (i) programmable routing control with reduced control overhead through inherent protocol support of a long-range control channel; and (ii) a modular SDN controller and an OpenFlow-like protocol improving the quality of communication in a wide range of IoT scenarios through supporting two alternative topology discovery and two flow establishment mechanisms. A comprehensive survey was conducted by authors in [12] regarding complementing IoT services through software defined networking and edge computing. The authors in [13] address the routing optimization problem in SDN-based IoT with TCAM capacity constraint. They first formulate the problem as a mixed integer linear programming problem and proved the problem was NP-hard. Then to solve the problem efficiently, they proposed several approximate algorithms, which solved the problem in two stages.

b. QoS Using SDN

Flexible QoS producing and SDN implementation results are perform best result. The SDN controller's heterogeneous network (HetNets) abstraction resulting from data idecoupling iand icontrol iplane ipaved ithe iway ifor ifast policy iimplementation iand inon-complex iand ieasy conformation. iIt alsoioffers ian ichance ito ienforce iper-flow rules iand iacts. In ithis ipara, ithe ireview ion iliterature iof QoS ienhancement istrategies iis idiscussed iin ithe iSDN networks. originally, ionly iQoS iis ibased ion ivideo streaming iand iis iguaranteed iin ithe iQoS. iThis ireview addresses itwo irecently irecorded iliteratures i[18-19].

2.2.1 Resource Reservation: Asset iReservation is one of the best approach iof ithe isystem including ithe iQoS. iA isystem iconsisting iof itwo icomponents imust ibe iintroduced iin iorder ito iimplement ithis istrategy:

a. Classification module

b. Rat shaping module

2.2.1.a iClassification iModule

The basic function performed by this component is to process the packet header. This results in the configuration and policies of the controller of SDN deciding the stream's priority.

2.2.1.b iRat ishaping imodule i

The flow specification and policies are particularly implemented by this module. In [20], authors proposed network slicing according to different application criteria and combined flows requiring similar QoS rates. Authors concentrated on network integration through successful network testing in this investigation. Authors proposed using the OpenFlow top-level QoS API to fulfill the QoS specifications. The proposed system was tested by a small test bed comprising of three ProCurve 5406 zl switches and four hosts. The device used in the test bed was NOX.

Flow QoS model was also a suggested by researchers in[31]. The system was based on the classifiers and it detects user-defined network traffic in multimedia streaming. To enforce itraffic ipreferences, upstream iand idownstream, icontroller tool Linux Traffic Control (LTC) was used. The controller which implements POX software in the system plane was the Raspberry Pi. In OVS-integrated OpenWrt routers, the proposed system was designed for native users in the tests.

A scheme is proposed in [21] which is based on the concept of rate-limiting long-lived flows. In this type of scheme, movements are assumed to consume relatively large amounts of network resources and affect other flows. In the code plane, the researchers suggested methods to idescribe iand ireshape ithe iflows iaccordingly. Theiproposed solution was tested using Mininet's four Open Switches. Floodlight controller was used in the test. Researchers supported end-to-end QoS bandwidth flows based on TC [22] in another form, proposed to enhance QoS flows.

2.2.2 Routing on the basis of flow

SDN operator, manages and configures the QoS flows in the Flow-based routing schemes. This routing scheme categorizes quality of service flows based on the predefined policies similar to the iasset ireserve i[23]. A workaround was proposed by authors in [24] to transmit the loss of the SVC video packet. The proposed scheme uses linear programming methods to route best effort traffic based on the shortest path and QoS paths for QoS traffic. The consequence of this scheme was the lowest level of QoS coverage for video playback, while the other layers were best transmitted only to improve quality Through defining header fields, an Open QoS approach distinguishes video streaming flows from other forms iof iflow. iThe iproposed imethod iwill iroute ithe ivideo istream ito ithe iQoS ipaths iwhile irouting ibest ieffort paths with the data streams[25]. Using three OpenFlow-enabled Pronto 3290 switches, one controller and three hosts. The proposed method iwill ibe itested. ilike ithis imethod i, for QoS itraffic i,HiQoS iused ithe ialgorithm inamed iEqual iCost iMultipath iRouting i(ECMP) [26]

I2.2.3 Packet Scheduling

The use of packet scheduling strategies and the management of a priority queue is another QoS achievement strategy. A proposed system is called the QoSFlow in this context, which used the stochastic fairness queues (SFQ) to give high priority to certain flows[27]. To check the performance of this system, three TPlink 1043ND switches are used. The[28] has recently introduced an API for setting up and controlling QoS. OVSDB is a QoS-based queue management tool for Open vSwitch. The planned system is modeled using a computer, four open vsswitches and three hosts. The architecture proposed is checked using the Floodlight API on the control and data plane. [21].

2.2.4 Procedures Contrast for QoS:

The SDN QoS can be compared based on following three criteria:

1. QoS sort
2. Guarantee (postponement)
3. Plane (Application)

METHODOLOGY

Figure 2 illustrates the architecture of the proposed approach. The key components of the proposed design are given below.

- Medical devices or WBAN Sensors
- Patient at office/home
- Sensors based on IoT
- Smartphone or PDA
- Software Defined Networking (SDN) Controller and Server

In the proposed approach, the WBAN sensors are embedded in the patient's body, while the IoT sensors are placed in the patient's surroundings, such as his bedroom or living room. The WBAN sensors collect the clinical health information and then transmit it to the mobile phone acting as an SDN switch, which then transmits the classified information to the backend server according to the controller-defined flow table. The advanced ICT infrastructure such as WiFi or 4G is used to carry out this communication.

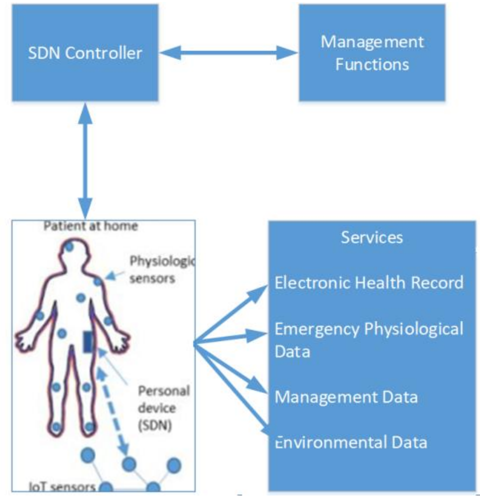

Figure 2: Design of Proposed SDN-IoT Healthcare System

3.1.1 PDA- SDN Switch:

The healthcare facilities are also improving with the raise in the world population particularly the elderly ones. Nonetheless, smart health monitoring systems are required to manage the constantly growing population. Moreover, the increased deployment of IoT devices in the health sector is also resulting in an increase in wireless traffic volumes. Therefore, for handling the expected increase in the number of patients requiring IoT healthcare and remote monitoring, a mobile phone is programmed through the SDN controller to serve as an SDN switch. This SDN controller is mostly located in a cloud server or a remote location.

3.1.2 Smart Health System Traffic

The following different forms of traffic are present in the smart IoT healthcare systems:

- Environmental information
- Physiological medical health data (PHMD)
- Parameters depicting Status of Sensors

3.1.3 WSN

In the presented model, ten sensors are used to deploy the WBAN for the measurement of PHMD representing vital parameters. Likewise, 5 sensors are employed by the proposed approach in creating IoT setting at the patient's home. The gateway is provided by the smartphones for communicating with the IoT network and WBANs. However, in this design approach, the smartphone only handles the communications with the server. Moreover, the WBAN and sensors communicate with the smartphone leading to the energy-efficient system. Different experiments will be performed for evaluating the efficacy of the proposed system.

3.2 Development of Prototype

The implementation of the proposed scheme, illustrated by Figure 3.1, is done for generating a testbed, which is followed by conducting varied experiments for measuring the system performance. An academic building within an experimental workplace is chosen for deploying the proposed system. The building is equipped with the following ICT tools.

3.2.1 WCN - Wireless Communication Network

3.2.2 Crossbow Mote

The range of operating voltage for the motes is from 2.7V DC to 3.6V DC in the proposed system.

3.2.3 Configuration of SDN

In the proposed approach, the health-related information is gathered and measured by the IoT smart devices and WBAN that is afterward passed on to the smartphone together with other functionalities needed by the WBANs and IoT. The mobile phone and SDN controller functions according to the flow tables, which are defined and embedded in the smartphone. In the SDN controller, the flow tables handle the information routing between sensors and servers.

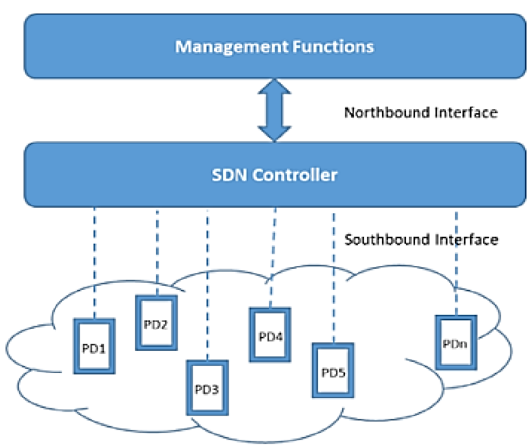

Figure 3. SDN Framework Used in Development of System Prototype

The management staff of the IoT healthcare system completely manages the information system and the programming of the flow tables as per the requirements of the patients/users. Moreover, these tables can also be modified in accordance with the required usage. The concept of SDN design is provided in Figure 3, which is also implemented via smartphone functioning as an SDN switch.

Table I: Flow Table Sample for SDN Switch

IP ADDRESS	SWITCH DPID	OUTPORT
10.0.0.1 (Health server)	1	11
10.0.0.2 (Data server)	1	12
10.0.0.3 (WBAN NODE ID 3)	1	13
10.0.0.4 (WBAN NODE ID 4)	1	14
10.0.0.5 (WBAN NODE ID 5)	1	15
10.0.0.6 (WBAN NODE ID 6)	1	16
10.0.0.7 (WBAN NODE ID 7)	1	17
10.0.0.8 (WBAN NODE ID 8)	1	1
10.0.0.9 (WBAN NODE ID 9)	1	2
10.0.0.10 (WBAN NODEID 10)	1	3
10.0.0.11 (WBAN NODE ID 11)	1	4
10.0.0.12 (WBAN NODE ID 12)	1	5
10.0.0.13 (WBAN NODE ID 13)	1	6
10.0.0.14 (WBAN NODE ID 14)	1	7
10.0.0.15 (WBAN NODE ID 15)	1	8

3.2.4 Functionality of Smart Phone

In the presented scheme, the smartphone functions as.

- Gateway for developing a link of IoT and WBAN sensors with the communication network
- A pre-procedure administrative unit that checks and handles information before forwarding that to the relevant host
- A tool that forwards the gathered information to the communication link

Moreover, the user is also provided with the option of checking the results and data of IoT and WBAN sensors on the smartphone.

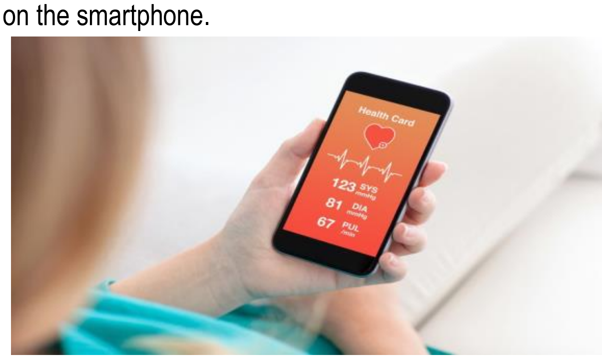

Figure 4: Smart Phone Utilized in IoT-based Smart Care System

3.3 Implementation and Testing

The prototype testing is done in two different ways, discussed as follows:

1. By collecting the data of the sensors from the network.
2. Through the communication between servers and smartphone

3.3.1 Sensor Data Collection

This step takes all the IoT and WBAN sensors into account. Here, the measured data is gathered and stored in the computing device linked with the smartphone as the emergency or routine information. A complete week data is stored for the extraction of data from all the sensors, thus leaving behind no sensor information in the evaluation phase.

The data gathered through the sensors is stored in tabular format as a comma-separated file (CSV). In the prototype, all the sensors are allocated a unique IP address, which is also stored in the CSV file for recognizing the sensors.

3.3.2 Communication between server and Smartphone

In the next stage of the analysis, a connection is made between the distant servers and smartphone using the internet connection offered by the Wi-Fi. This stage involves the transmission of stored information to the server to process and analyze the information further. The allocated static IP addresses help in the recognition of each sensor's data. The gathered data is then arranged under the following columns.

1. Switch DP-ID, which is fixed at 2
2. IP Address
3. Switch Output Port

The following table shows a sample of the gathered information.

Table II: Transmission of CSV Stored Data

IP ADDRESS	OUTPUT PORT
10.17.1.1	1
10.17.1.2	2
10.17.1.3	3
10.17.1.4	4
10.17.1.5	5
10.17.1.6	6
10.17.1.7	7
10.17.1.8	8
10.17.1.9	9
10.17.1.10	10
10.17.1.11	11
10.17.1.12	12
10.17.1.13	13
10.17.1.14	14
10.17.1.15	15

The smartphone in the proposed scheme is responsible for transmitting data to the defined destinations. Two main destinations have been defined here for receiving two kinds of data, i.e.

1. Data of WBAN sensors
2. 2. Data of IoT Sensors

3.3.3 Communication Path

The open flow between server and Smart Phone forms the basis of the communication setup in this experimental procedure. A secure communication channel has been set up here that ensures no type of hacking or similar threats. Moreover, the flow tables' installation in the smartphone is also based upon the OpenFlow. The key entries of the flow table include matching networks and Mac address, path identifiers for the smartphone, and mobile output port. A virtual network is formed by using mininet, a known network emulator that can instantly create virtual networks. Here, a virtual network is formed by the mininet through the creation of hosts, switches and other essential network elements. Moreover, the SDN based controller is also run by it for the experiment.

Table III: Communication Setup of the Proposed Approach

Destination Nodes	Inter-departure time	Receiver ports	Simulation Time (sec)	Size of Packet	Protocol
10.17.1.2	IDT	1009	1,440,000	36	TCP-IP
10.17.1.1	IDT	1010	1,440,000	36	TCP-IP

3.3.4 Bellman-Ford Algorithm Implementation through POX controller

POX is a controller based on python that is employed in the simulations here. The effectiveness of the proposed approach is evaluated through the Attmpls topology that has been implemented within the mininet. The topology of the network is believed to be a directed graph in which the Bellman-Ford is employed for defining the flow tables with the aim of attaining lower delay than the benchmark algorithm.

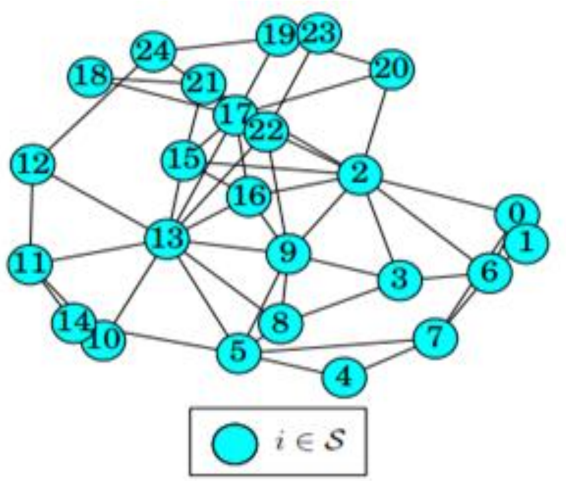

Figure 5: Attmpls Topology

The traffic generation module named D-ITG [16] is employed to evaluate the performance of the algorithm. The traffic is generated by the D-ITG in accordance with the requirements specified by the user with some probability distribution. The Bellman-Ford algorithm is used for computing the shortest route with the help of the Python network library.

METHODOLOGY

This section presents the findings of the experiments carried out for analyzing the developed prototype. A highly advanced tool called the "Distributed Internet Traffic Generator" D-ITG has been used for assessing the gathered data and network parameters. This software tool can generate and measure the traffic as per the pattern that has been defined with the help of probability distributions. The key modules of D-ITG include:

- Traffic Parameters Decoder (ITGDec)
- Receiver (ITGRec)
- Transmitter (ITGSend)

The following figure shows the employed D-ITG interface during experimental analysis.

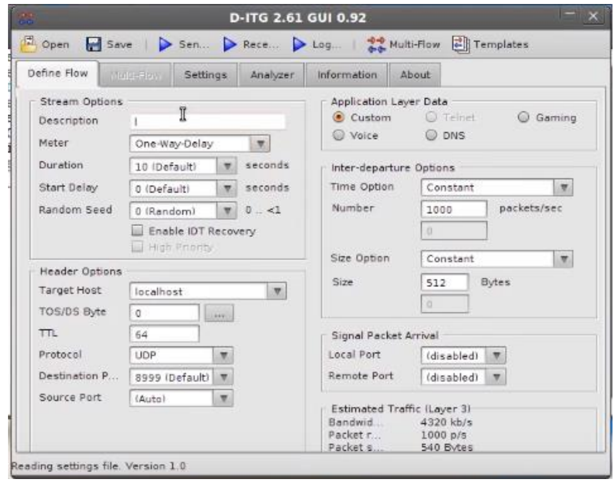

Figure 6: D-ITG Graphic User Interface

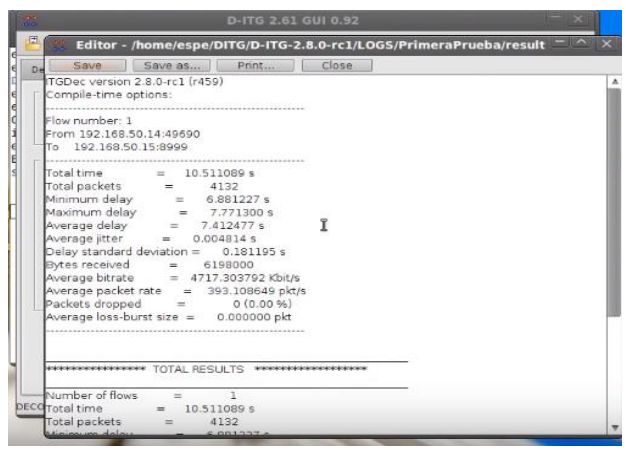

Figure 7: Execution of D-ITG Script

The modules discussed above are employed for generating data in line with the experiment described previously. Table 4 provides a summary of the complete experimental results.

The overall results indicate a significant drop in the mean jitter and mean delay values compared to the benchmark study, which is mainly because of the use of the Bellman-Ford algorithm and prioritization of emergency data. Moreover, no packet loss and a maximum number of received bytes have been observed simultaneously. The findings indicate that the QoS of IoT-based smart healthcare systems can be improved effectively for delay-sensitive traffic through the use of SDN technology. Furthermore, the integration of the SDN paradigm has not just helped in improving the performance of the system but also permitted the management of massive traffic volume generated by the IoT healthcare systems.

Table IV: Results of Simulation

Parameters	Proposed algorithm	Benchmark results [17]
Total Packets	1095	1000
Time (sec)	86400	86400
Mean Delay (sec)	0.00015	0.00030
Dropped Packet Percentage	0	0
Received Number of Bytes	39420	39420
Standard Delay Deviation	0.000263	0.000371
Mean Jitter (sec)	0.000120	0.000233

CONCLUSION

The healthcare industry is currently facing several challenges due to the aging population, increase in chronic diseases and high cost of medical services. In such situations, exquisite advantages have been offered by the IoT smart healthcare systems for enhancing the efficacy and quality of the medical facilities offered to the patients worldwide. Nevertheless, the massive traffic generated by the heterogeneous IoT devices has made it impossible for the traditional networking architecture to fulfill the QoS requirements of smart systems. Taking this into account, the incorporation of SDN technology with IoT based healthcare systems has been proposed in this study for achieving the required QoS. To ensure the on-time delivery of emergency information, the Bellman-Ford algorithm is used in the SDN controller to find the minimal delay paths. The simulation results and their comparison with the benchmark work clearly indicate the efficacy of the proposed scheme.

The future work will focus on using an optimization technique for finding optimal paths considering the QoS nature of the traffic. Furthermore, the machine learning techniques will be implemented to achieve the QoS for smart healthcare systems. The IoT is generating big data and current algorithms cannot search optimal paths considering the diverse nature of the traffic. Thus, the future work will utilize the machine learning and optimization techniques for traffic management of the IoT traffic.

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