Hindawi
Wireless Communications and Mobile Computing
Volume 2022, Article ID 3150756, 11 pages
https://doi.org/10.1155/2022/3150756

Research Article

SDN-Driven Internet of Health Things: A Novel Adaptive Switching Technique for Hospital Healthcare Monitoring System

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Received 28 February 2022; Revised 9 May 2022; Accepted 17 May 2022; Published 15 June 2022

Academic Editor: Ghanshyam Singh

In the last decent, the number of Internet of Things (IoT) health-based paradigm reached to a huge number of users, services, and applications across different disciplines. Thus, hundreds of wireless devices seem to be distrusted over a limited or small area. To provide a more efficient network, the software-defined network (SDN) thought to be a good candidate to deal with these huge number of wireless users. In this work, after a novel SDN algorithm is proposed for the hospital environment, it is also designed and integrated into an Internet of Health Things (IoHT) paradigm. The novel algorithm called adaptive switching (AS) is proposed as a novel adaptive access strategy based on adaptively hoping among existing Go-Back-N and Selective Repeat techniques. Finally, the throughput performance of the proposed AS method is compared with the performances of traditional Go-Back-N and Selective Repeat ARQ methods using the developed MATLAB simulation. For this, an optimal P_{error} rate that the network should prefer to switch either from Go-Back-N to Selective Repeat or from Selective Repeat to Go-Back-N method to maximize the network throughput performance is determined. The evaluated results are also confirmed by theoretical calculation results using well-known Mathis throughput formula. It is observed from the simulation results that the best throughput performance can be evaluated, when AS switches to Go-Back-N if the P_{error} is less than 3.5% and it switches back to Selective Repeat when the P_{error} is greater than 3.5%. By this way, it is also observed that the throughput always has its best possible results for all P_{error} rates and up to 37.52% throughput improvement is provided by the use of novel proposed adaptive switching (AS) algorithm.

1. Introduction and Related Work

1.1. Introduction. The IoT is a rapidly evolving ecosystem that connects hardware, computing devices, physical items, software, and animals or humans over a network, allowing them to interact, communicate, gather, and share data [1, 2]. From industrial applications to e-healthcare applications, there are many distinct kinds of IoT services [3–5].

In [6], the authors introduced the development in the rising technologies and the framework for EC-IoT-based SG (edge computing for IoT-enabled smart grid), with its implementation requirements. And in [7], the authors provide the current operations of the healthcare system and discuss the mapping of these operations into the architectural diagram. Smart wearable/implant sensors, machine devices connected to or within a human body for monitoring in a hospital digital healthcare system, are the goal of this study, to gather data about the person's state of health for heartbeat, blood pressure, glucose level, etc., via the technologies of wearable sensors [8]. The overall proposed structure of the software-defined network-driven Internet of Health Things paradigm is given in Figure 1. In this figure, the

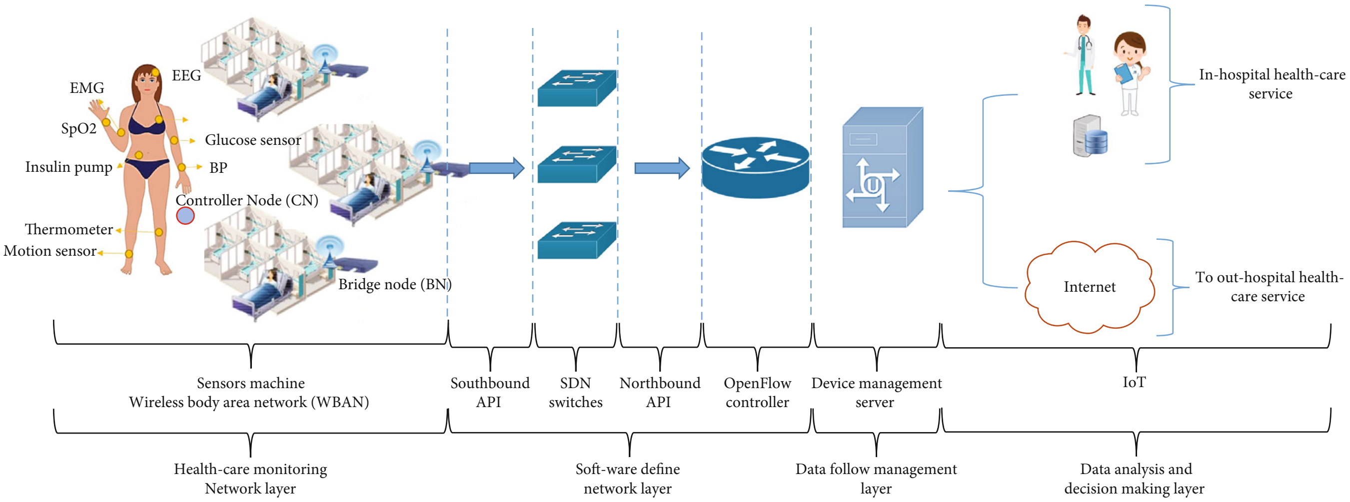


Figure 1: Proposed structure of the software-defined network-driven Internet of Health Things (SDN-IoHT) paradigm.

end-to-end (ETE) data flow in the proposed structure can easily be followed.

The control types of wireless body sensors used in hospital-based healthcare applications can be categorized into 3 subcategories as centralized control, decentralized control, and distributed control types [9]. In the case where the single node in a centralized control system has a global view and knowledge of the network, and it decides whether a node's functionality is required or not, the node should be active or inactive. In the case of the having a noncentralized control system, the categorization of the nodes will be done in several groups where there will certainly be a single node in each group (as the central node). The activity of these nodes is determined by interactions among the core nodes of different groups. When the distributed control is in use, there will be no grouping or no central control nodes, and also for network-wide decision-making, such as selecting the active nodes over the network region, all the nodes in the network will communicate with each other dynamically.

In this work, the throughput performance of decentralized control of wireless body sensors in hospital-based healthcare applications is investigated. And, since the SDN really does distinct from the control plane to the data plane, it is considered to be a good candidate for controlling such a network; thus, a new structure for SDN-driven Internet of Things is proposed for e-health applications.

In Figure 1, a multifloored hospital building structure is considered with several sections distributed in each floor of the hospital, where each of these sections consists of at least six and up to seven patient beds. The machine sensors are connected to the whole body of the patient to monitor his/her biological or vital signals and their other activities. Each of these sensors is also equipped with a wireless transceiver, and the gathered data are transmitted to the controller node over the wireless channel (each patient has his/her own single controller node which is located close to him but not attached to his/her body) using the standard of IEEE 802.15.6. The most important function of the controller node (CN) is to receive the data and transmit it to the bridge node (BN). In this work, the layer up to this point is called as "the healthcare monitoring network layer" or "the data plane layer."

The second layer above the first one is "the software-defined network (SDN) layer," for which the healthcare monitoring network layer can be considered as the data plane for it. In each of the sections, the data are collected and transmitted to the BN either by a multihop or by a single hop. Then, the SDN controller selects the appropriate path for the data gathered by the CN over the hop or multihop and delivers them to the BN using IEEE 802.15.6 standard (the sensors collect data, which is then sent to the controller based on 802.15.6 standard). However, to increase the system performance, the CN will also use the novel proposed technique called "adaptive switching (AS) technique" as the second function of the SDN controller.

The third layer which is called "the IoT layer" is in charge of the data follow management and the making of decision. The data are forwarded either to the healthcare services inside the hospital (and represented by doctors or nurses before being stored in the data storage devices) or to other hospitals and the intelligent cloud system over the Internet.

The main contribution of this work is done on the data link layer of OSI (open systems interconnection) model where a novel adaptive switching (AS) technique is proposed which is a combination of traditional automatic repeat request protocols. This technique is simulated on a hospital healthcare monitoring system to be used with the SDN-driven Internet of Health Things (SDN-IoHT). As the result of this work, it is shown that the throughput performance of hospital healthcare monitoring system is improved by the proposed technique.

The major contributions provided in this work can be summarized as follows:

(i) An SDN-driven Internet of Health Things (SDN-IoHT) network is designed for the hospital monitoring system in real time which comprised of three layers, "healthcare monitoring network layer," "SDN layer," and "IoT" layer

Table 1: State of Arts Comparison.

Pub. year [ref. no.]	Protocols/methods	Metrics	Highlight
2019 [10]	SDN routing based	(i) Throughput (ii) End-to-end delay (iii) Energy consumption (iv) Successful transmission	(i) Proposed an energy-aware and controller-based routing algorithm (SDN routing) with a new interface protocol (WBAN flow) (ii) Proposed a new architecture consisting of data, control, and application planes for the SDN-based WBAN environment
2018 [11]	Software-defined WBAN (SDWBAN)	—	(i) Proposed new framework based on lack of current WBAN architectures and challenges such as heterogeneous WBAN traffic handling, static architecture, mobility management, traffic priority management, secured authentication, network reconfiguration, energy efficiency
2017 [12]	Software-defined network-service function chain (SDN-SFC)	(i) Total distance (ii) Overload (iii) Time cost	(i) Proposes combined software-defined network-service function chain (SDN-SFC) with heuristic SA algorithm to reduce IoT health-based data transmission time (ii) Considering load-balancing for remote healthcare system
2015 [13]	SDN-cloud computing (CC) based	—	(i) Generalized software-defined cloud-based architecture for virtual hospital has been proposed (ii) Future possible open research issues and challenges have been discussed to provide an interesting and enormous research effort for near future
2015 [14]	Centralized controller using SDN	Response time	(i) Proposed a design of the elastic health IoT structure, which deals with both intelligent health monitoring and emotional care (ii) A health IoT framework with software defined is proposed which separates the application from the underlying physical infrastructure (iii) Proposed framework enables elastic control and management of the physical infrastructure and speeds up the innovation of various healthcare applications

(ii) The novel proposed switching technique called adaptive switching (AS) which makes switching among one of the traditional Go-Back-N and Selective Repeat methods according to the packet error rate of the network at an instant is simulated, and it is shown that the throughput performance of real-time hospital monitoring system is improved

(iii) Additionally, a multihop technique is also utilized to present alternative paths to CN and to overcome the direct transmission failures

The rest of the paper is organized as follows.

The MAC protocol of the Go-Back-N and selective repeat ARQ is explained in Subsection 2.1; then, in Subsection 2.2, the proposed adaptive switching (AS) technique is described. In Section 3, the evaluated simulation results and the provided throughput performance improvement are presented. Finally, in Section 4, conclusions are made and future research approaches are suggested.

1.2. Related Work. The limitations of the proposed frameworks/design/algorithms in Table 1 are as follows:

(i) Single work considered the important metric quality of service which represented by throughput in the SDN environment for healthcare applications

(ii) None of the previous work consider the packet error rate in the SDN environment for healthcare application

(iii) Finally, none of the previous work design framework that taken into account MAC protocol in the SDN environment for healthcare applications

Only a few research has been done on the SDN healthcare-based paradigm thus far. SDN is a promising technology that defines new network communication design and management techniques. Despite the fact that it is a broad emergency, IoHT is still in its infancy, with a huge field of study for different issues such as scalability and heterogeneity, with existing IoHT paradigm and so forth.

In [10], for the healthcare paradigm, a WBSN architecture based on the SDN paradigm with a novel energy-aware routing algorithm is presented. As a result, for e-healthcare architecture, a WBSN architecture based on the SDN method with a novel energy-aware routing algorithm is presented and built.

In [11], a framework for software-defined WBAN (SDWBAN) is designed and proposed that brought the idea of SDN technologies into WBAN applications. By this concept, decoupling the control plane from the data plane and having more programmatic control would assist to remedy the current deficiencies and challenges of WBAN.

In [12], the use of SDN is proposed in addition to service function chain (SFC), and instinctive simulate annealing (SA) methods, in e-health service networks, decrease the time it takes for IoT data to be transmitted. The SA technique is proven to be more effective in reducing data transmission time for multiple users; however, the greedy algorithm looks like a good candidate for more users. They designed a side-by-side e-health network by the proposed methods.

In [13] for WBSN, a virtual hospital architecture based on SDN is recommended. The inclusion of cloud architecture into WBSN for virtual hospital architectural ideas leads in a new and fundamental architecture that may benefit from SDN and reduce the intricacy of cloud architecture.

[14] proposes and presents a flexible network architecture that can handle intelligent health monitoring and emotional care. Particularly, an architecture based on an SDN system named e-health IoT is developed through separating the application plane from the physical infrastructure. The healthcare services acquire the ability to customize, transfer, and process their own gathered data. Several applications are permitted on a shared infrastructure due to emotion feedback via well-defined APIs, lowering total expenses. The physical infrastructure may also be controlled and managed in a flexible manner. In the study, the application plane of the proposed architecture is focused on.

In [15], a secure IoHT system that is integrated with the WBAN is demonstrated and investigated. Reliable cryptoprimitives were applied to make dual communication systems which could be guaranteed the transmission privacy as well as build an entity authentication for the machine sensors, the CN, and the edge of the network.

In [16], low-power consumption, transmission reliability, latency, data speeds, and security are all examined in the WBSN domain. Furthermore, the authors examined the needs and requirements of WBAN in a traditional e-healthcare system in order to determine how such systems are able to communicate effectively in the home environment network.

[17] presents and investigates a mathematical equation for the in-body to off-body channel statistical model, which may explain the signal traveling between the transmitter and receiver antennas. The research is based on a three-dimensional virtual human body model.

The authors looked at a novel design of IoT e-healthcare paradigms in [18], which they called a secure e-healthcare IoT-based paradigm for BSN-care.

In [19], the nonstatic e-healthcare IoT paradigms are suggested with an end-to-end security mechanism. The authors of the study used the idea of fog layers in IoT to provide seamless mobility for the fog extending the cloud system to the network's edge.

In [20], the applications of IoT in the e-healthcare industries are investigated and presented, revealing the intelligentization trend of future research in e-healthcare IoT-based paradigms.

An on-body sensor device with solar energy harvesting and a low-power transmission paradigm is explored in [21], allowing for the implementation of an autonomous WBSN. Furthermore, the information gathered from the human body is shown on a web-based smartphone application.

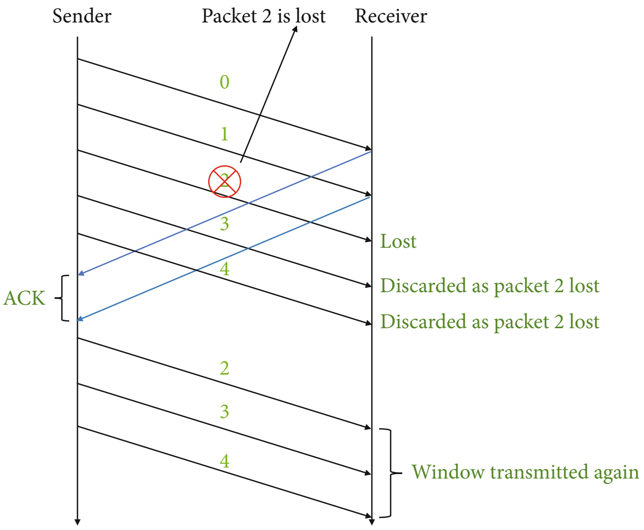


Figure 2: The working principle of the Go-Back-N method.

The effect of power allocation and packet size determination on the performance of an e-healthcare IoT-based system is addressed and studied in [22] for the wireless medium. Three protocols are suggested in the study: a power level decision, a power level and packet size choice, and a global link decision.

A new IoT-aware smart hospital system is introduced in [23]. The proposed system is capable of handling emergency circumstances effectively. Interoperability has been a major challenge for IoT researchers and developers.

But in [24], an IoT-based semantic interoperability paradigm is proposed, which enables semantic interoperability for heterogeneous IoT devices. Doctors are able to communicate with their patients since the collected data was semantically interpreted and conveyed in a meaningful way.

[25] establishes a developed concept connecting cloud computing and IoT: cloud IoT-health (CC-IoT) solutions. The idea of the CC-IoT is explored, as well as a number of important integration problems, in order to show a realistic vision that integrates current CC and IoT mechanisms in e-healthcare applications.

A privacy protector is suggested in [26], which safeguards the privacy of the patient data gathered. In privacy protector, the Slepian-Wolf-coding-based secret sharing is used to overcome a variety of security measures.

A type 2 fuzzy ontology–aided recommendation system for IoT-based healthcare is proposed in [27] to efficiently monitor the patient's body. This system greatly increased the accuracy of predicting a patient's condition as well as the accuracy of medical and nutritional suggestions.

In [28], harvesting energy IoT health-based paradigm has been developed, with the goal of reducing outage probability via interwireless body area network collaboration.

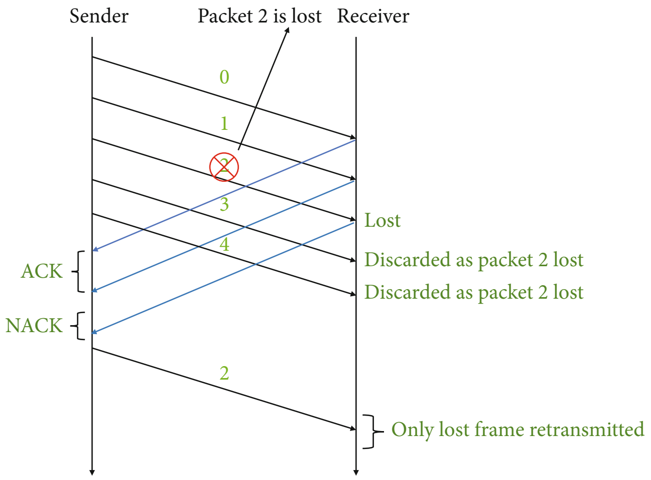


Figure 3: The working principle of the Selective Repeat method.

Finally, [29] investigates WBSN in IoT health-based applications: towards delay and energy consumption minimization.

However, to the best our knowledge, in none of these works,

(i) the developed SDN-based driven Internet of Health Things for hospital healthcare applications are considered

(ii) SDN integrates with the wireless body area network

(iii) an adaptive switching access technique has been considered for SDN-based driven Internet of Health Things

2. Proposed MAC Protocol

MAC protocols are needed to regulate communication between wireless devices over a shared medium. The commonly used wireless body area network MAC protocol is a hybrid access technique, and it comprises of carrier sense multiple access collision avoidances (CSMA/CA) and time division multiple access (TDMA) (802.15 s.6). In this work, although the intra-WBAN communication is not considered, the communication between the controller nodes and bridge node is regulated in each section of the hospital.

For this purpose, an access technique called adaptive switching (AS) is proposed in this study for determining the optimal packet loss rate that will be used to switch between Selective Repeat and Go-Back-N automatic repeat request (ARQ) methods. The proposed method is used on the controller nodes to wirelessly access the shared medium broadcasted by the bridge node.

2.1. Understanding Go-Back-N and Selective Repeat ARQ Methods. The working principles of Go-Back-N (GBN) and Selective Repeat (SR) ARQ methods [30] are given in Figures 2 and 3, respectively, for comparison. And all other parameters are also created eventually by the developed simulation program.

In Go-Back-N method, the frames are transmitted continuously and the receiver only ACKs the highest sequence-numbered frame received among the packets in the current window. Since the ACK of this packet will come back after a round-trip delay, there is also a timeout value (retransmission timer (RTT)) to decide whether to retransmit the same packet or to wait for a while. If the ACK does not arrive at the transmitter within this timeout value, the sender retransmits all the frames that are not ACKed in the current window. Thus, CWND minus N (where CWND is the current window size and N is the number of frames transmitted in the current window during the round-trip time) succeeding frames that were probably already transmitted during the round-trip delay will be retransmitted. For these retransmissions, a buffer is needed at the transmitter side and the receiver side does not have to buffer the frames. Because of these properties, GBN is more feasible and less complex and also requires less message overhead, and the unique disadvantage of it is we have to retransmit all the packets which are in the window but after the last acknowledged packet. That means GBN will waste the bandwidth in case of a packet loss but gain the bandwidth when no packet losses occur.

For the example in Figure 2 in which the window size is 3 and Go-Back-N is used, since pkt-1 is lost, only the last successfully arrived packet (ACK-0) of the window is acknowledged (ACK), so some of the next 3 packets outside the window cannot be taken in before receiving the ACK-1 and cannot be transmitted. Then, when all the packets are received and acknowledged but ACK-2 is lost on the returning way, pkt-2 will be considered as a lost packet by the system and the source node will retransmit it pct-2. This will cause unnecessary retransmissions. But on the other hand, the advantage of Go-Back-N is that we do not need to make ACK transmission from destination to source for each of the packets, and it is enough to transmit only the ACK of last received packet in the window.

However, in the Selective Repeat method for which an example is illustrated in Figure 3, even the packets are again transmitted continuously without waiting, the receiver

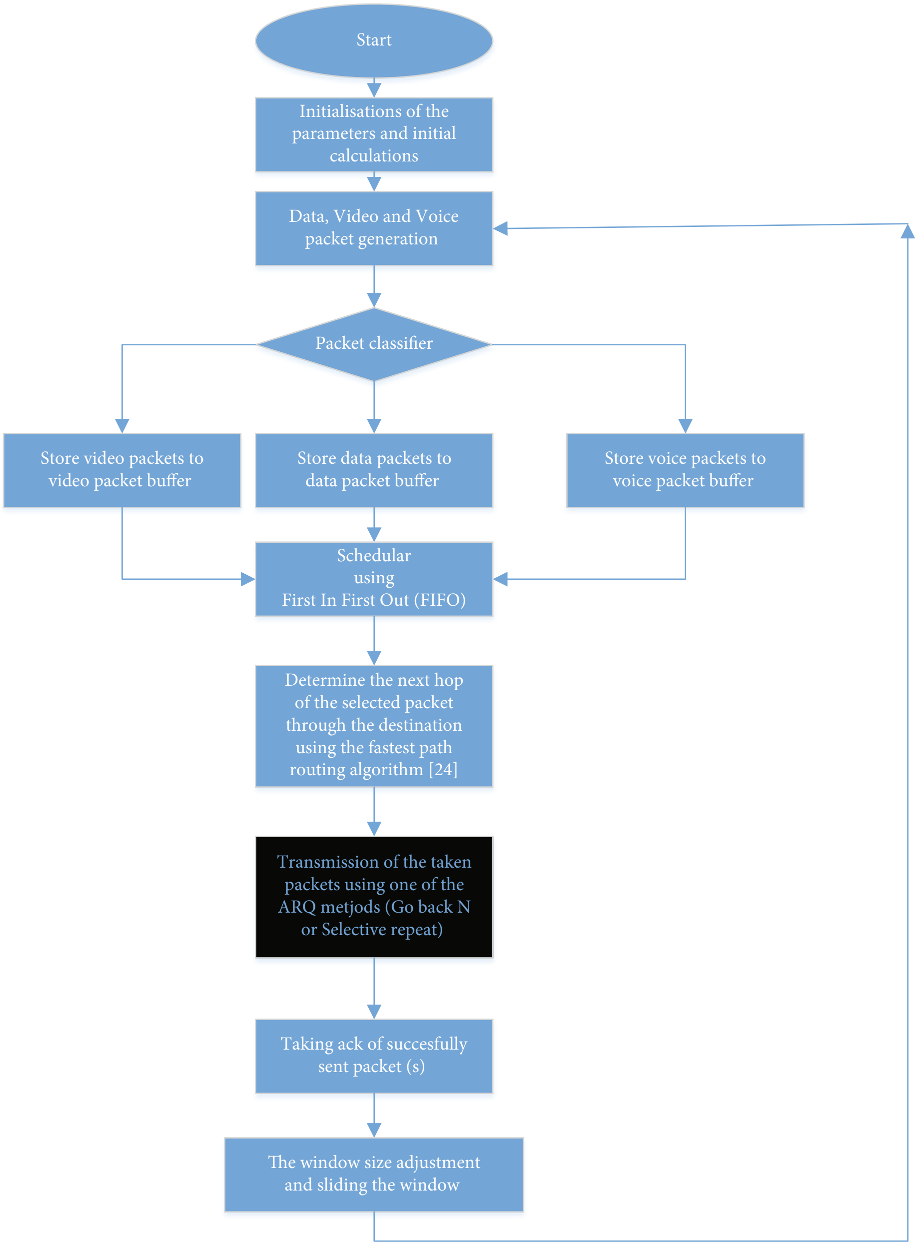


Figure 4: The flow chart of the process of proposed technique running on each controller node (CN) in the network where the sliding window that uses one of two ARQ methods is highlighted in black color.

ACKs not only the last successfully received packet but also ACKs all successfully received frames. Therefore, the transmitter will have the opportunity of retransmitting (repeating) only the unacknowledged frames when their own retransmission timers (RTT) expire. This method is known as the most efficient but also the most complex method, and buffers are needed at both transmitter and receiver sides. The disadvantage of this method is the usage of extra bandwidth for acknowledging all the packets.

Therefore, in some network conditions where there is low probability of error, Go-Back-N can be useful, but if there is more than a certain probability of error, Selective Repeat will be more useful. In this work, the proposed adaptive switching method will automatically switch between these two methods dynamically considering the current probability of error in the network.

The exact location of the proposed adaptive switching technique in the framework is given in Figure 4.

2.2. The Proposed Adaptive Switching (AS) Technique. Several studies and modifications were already made in the literature to increase the bandwidth utilization and to achieve a better quality of the network. It is known that each of the ARQ methods among “Stop and Wait” (SW) or “Go-Back-N” (GBN) and “Selective Repeat” (SR) may provide better results than others for different traffic conditions. However, at the beginning, it is not easy to predict which one will give the best results for a specific network. But since the P_{error} rate

Table 2: The parameter values used in the simulation and in the calculations.

Parameter	Value
Node number (N)	6 nodes
Buff size	1000 buffers per node
Pocket-size	1544 bytes [32]
Data rate	6 packets per sec
Receive window size (RWND)	65536 bytes [32]
Transmitter current window size (CWND)	1500 bytes (=MSS) [32]
Distance (d)	1000 km [32]
Maximum transferable unit (MTU)	1540 bytes [32]
Total header length (TCP\IP)	40 bytes [32]
Bandwidth of T3 channel (BW)	45 x 10^6 bits per sec [32]
Maximum segment size (MSS)	1500 bytes (MTU - total header length [32]
Probability of error (P_{error})	Ranging from 1% to 10% [32]
1 mile propagation delay	0.02 seconds
S threshold	65536 bytes (=RWND) [32]

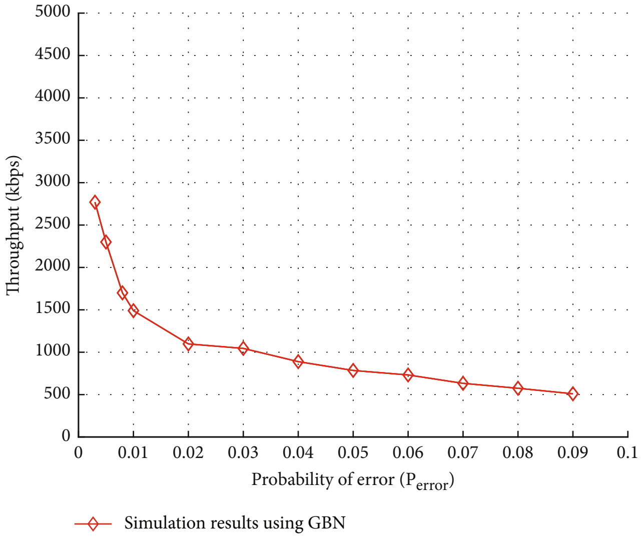


Figure 5: The evaluated expected theoretical results of expected throughput for GBN vs. different probability of error rates.

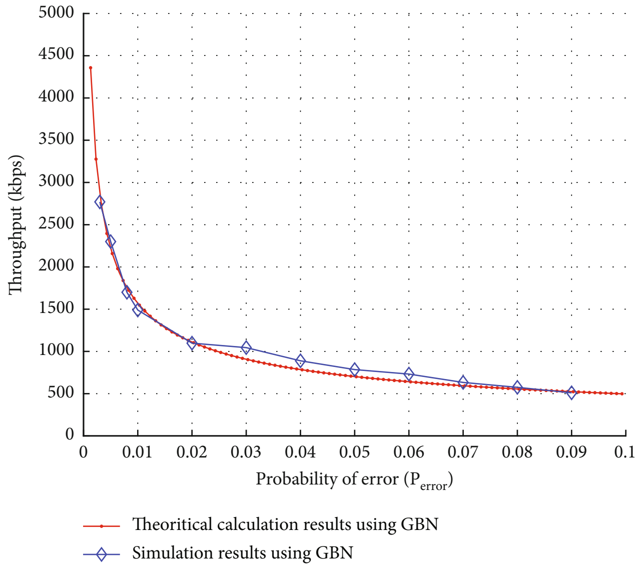


Figure 6: Confirmation of the evaluated simulation results under different packet loss rates for GBN by comparing the results evaluated using the Mathis formula.

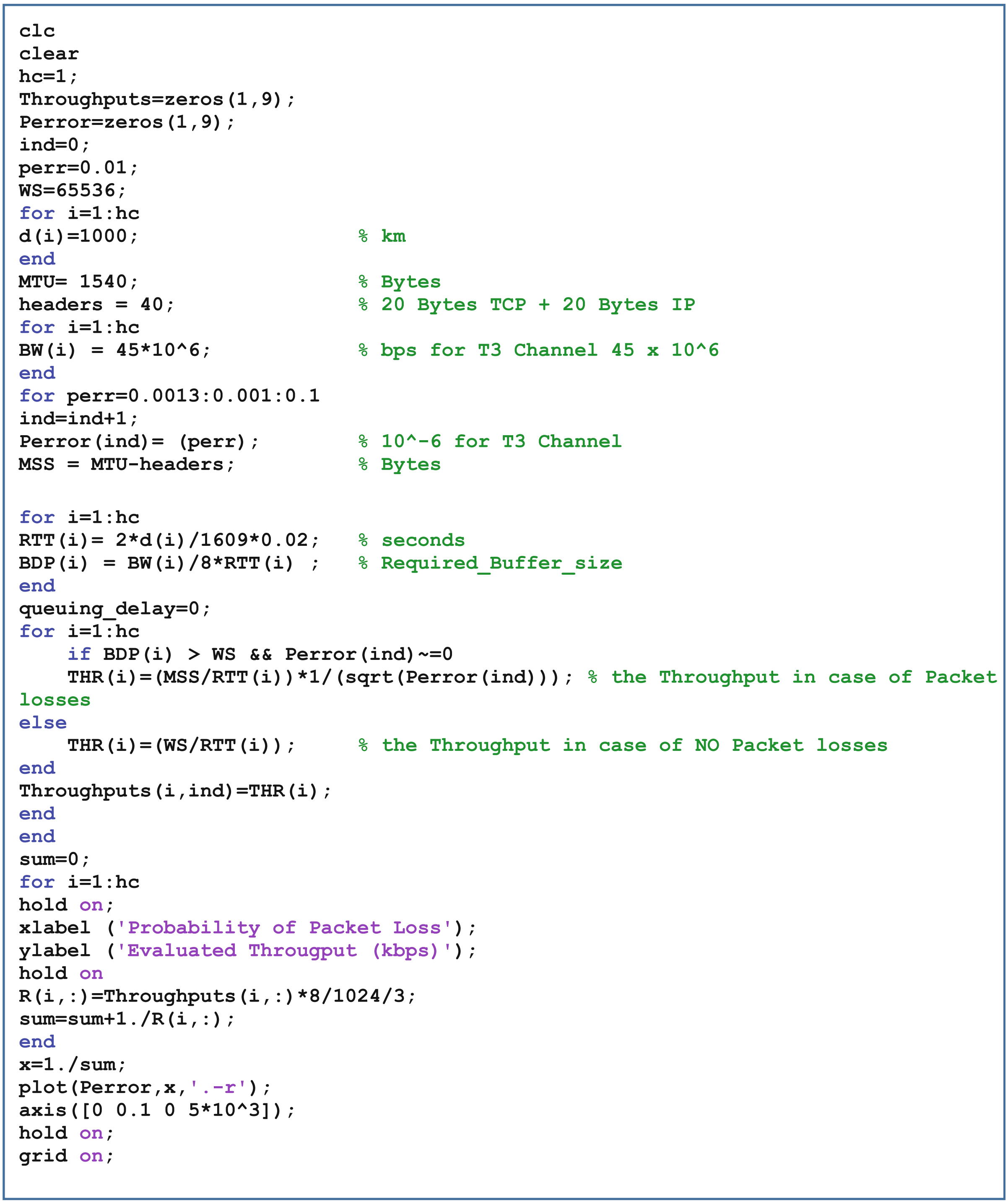
of a network is a stochastically predictable and also sensible value in real time, the novel AS method is proposed to control the wireless access of the controller nodes to the shared medium by using the evaluated optimal P_{error} rate of the network to adaptively switch between different ARQ methods for the known traffic conditions.

In the use of GBN, a trade-off may be faced, such that using less ACK will increase the throughput performance, where the packets which were already sent successfully after the lost (and unACKed) packet will also be retransmitted which will cause extra retransmissions and reduced throughput performance. On the other hand, using SR may also have another trade-off such that using more ACK will decrease the throughput performance; however, the packets already sent successfully after the lost packet will not be retransmitted which will not cause a reduce on throughput performance. In this work, an adaptive access (AS) technique is proposed to switch between these ARQ methods when specified optimal P_{error} rate is experienced. For this purpose, the simulation results are evaluated using one of GBN or SR one at a time; then, it is expected to have an improved network throughput performance by dynamically switching between these methods when the system reaches to determined optimal P_{error} rate.

The flow chart of the proposed technique that is given in Figure 4 is running and controlled by the control plane of the SDN. In this figure, it is shown that each controller node forwards the packet to the bridge node based on initial calculations made by control plane in SDN and the system initializes the default simulation parameters such as buffer size, packet size, MTU (maximum transferrable unit), window size, bandwidth, and P_{error}. Then, using the specified functions, each node generates random numbers of video, voice, and data packets and stores them into their corresponding buffers. Then, the classifier function analyses the packets and classifies them according to their types. Finally, the scheduler function schedules the selections of the packets from each of these buffers according to FIFO (first in first out) scheduling algorithm. Then, the fastest path routing algorithm [31] is implemented for each packet to define their routes and to transfer them to their own next nodes on their own calculated routes.

3. Simulation and Discussion

The suggested protocol's performance is assessed in this section. By this way, the developed MATLAB simulation program is used to implement the proposed AS method to provide an improvement on network throughput



```
clc
clear
hc=1;
Throughputs=zeros(1,9);
Perror=zeros(1,9);
ind=0;
perr=0.01;
WS=65536;
for i=1:hc
d(i)=1000;                  % km
end
MTU= 1540;                  % Bytes
headers = 40;               % 20 Bytes TCP + 20 Bytes IP
for i=1:hc
BW(i) = 45*10^6;            % bps for T3 Channel 45 x 10^6
end
for perr=0.0013:0.001:0.1
ind=ind+1;
Perror(ind)= (perr);        % 10^-6 for T3 Channel
MSS = MTU-headers;          % Bytes

for i=1:hc
RTT(i)= 2*d(i)/1609*0.02;   % seconds
BDP(i) = BW(i)/8*RTT(i) ;   % Required_Buffer_size
end
queuing_delay=0;
for i=1:hc
    if BDP(i) > WS && Perror(ind)~=0
    THR(i)=(MSS/RTT(i))*1/(sqrt(Perror(ind))); % the Throughput in case of Packet
losses
else
    THR(i)=(WS/RTT(i));     % the Throughput in case of NO Packet losses
end
Throughputs(i,ind)=THR(i);
end
end
sum=0;
for i=1:hc
hold on;
xlabel ('Probability of Packet Loss');
ylabel ('Evaluated Througput (kbps)');
hold on
R(i,:)=Throughputs(i,:)*8/1024/3;
sum=sum+1./R(i,:);
end
x=1./sum;
plot(Perror,x,'.-r');
axis([0 0.1 0 5*10^3]);
hold on;
grid on;
```

Figure 7: The MATLAB code used for GBN theoretical calculation results using the Mathis throughput formula.

performance. Table 2 lists the parameters used in the simulation and their default values, as well as the default values utilized in the calculations.

Figure 5 shows the evaluated throughput values versus different packet error rates ranging from 0 to 0.1 (10%). And it is seen from the graph given in Figure 5 that the TCP throughput is very sensitive to error rates and packet losses. And only an average of 1% packet loss rate restricts the TCP throughput to be less than 1500 kbps. The shape of the curve also reveals that greater loss rates dramatically affect TCP throughput too. If no packet losses occur, the window size (CWND) steadily increases until a corrupted/lost packet is detected or the RTT is over or the receiver advertises an insufficient receive buffer.

On the other hand, after the GBN and SR methods are separately simulated as event-driven MATLAB simulations, the theoretical Mathis throughput graph is also evaluated for confirmation of the evaluated simulation results and

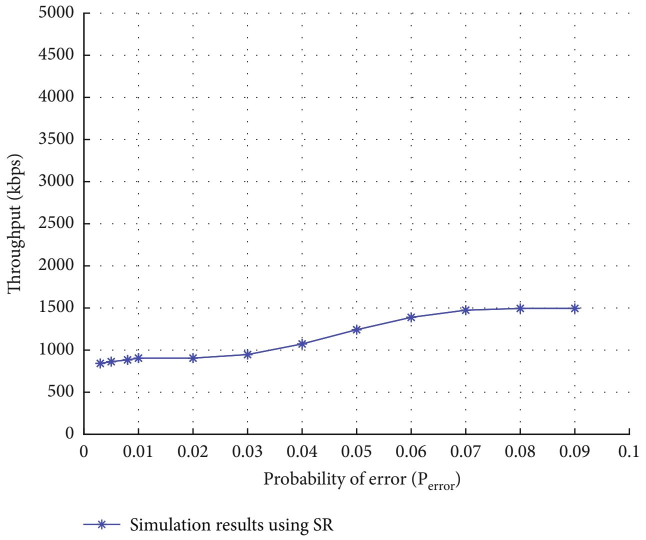


Figure 8: Evaluated simulation results under different packet loss rates for SR.

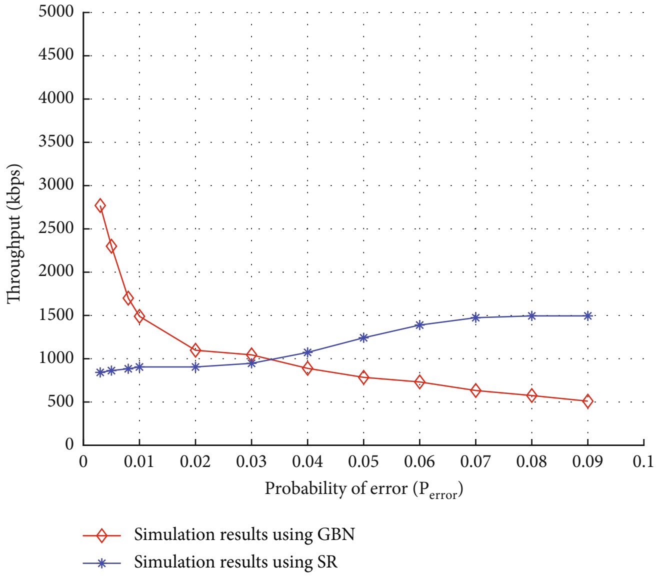


Figure 9: Comparison of the results of GBN and SR methods.

calculation results. When the simulation results are evaluated for different P_{error} rates using GBN and plotted holding on the calculation results evaluated by the Mathis formula [32, 33] for confirmation purpose, it is seen in Figure 6 that the experimental simulation results almost exactly match with the theoretically calculated throughput results.

The theoretical results in Figure 6 are evaluated analytically for GBN using the Mathis throughput formula [31] with the parameters given in Table 1 [32]. The MATLAB code implementation of theoretical calculations is given in Figure 7. On the other hand, simulation results are evaluated using a separate event-driven MATLAB simulation program in which GBN and SR methods are used. It is also shown that the evaluated outputs also match the outputs evaluated in [33].

In Figure 6 it looks like, as the probability of error increases, the throughput almost remains constant, but in fact, it just starts to slowly converge to zero throughput by the increased probability of error. Because by the time the probability of error will increase to 1 (100%), the throughput will obviously converge to 0.

On the other hand, when the simulation results are reevaluated using SR instead of GBN for the same P_{error} rate scale, it is seen in Figure 8 that the experimental simulation results tend to increase by increasing P_{error} rate.

It is seen in Figure 9 by the comparison of the evaluated simulation results under the same packet loss rate scale that GBN and SR can provide different throughput performances with different trade-offs. However, it is clearly seen from the resulting graph that GBN provides better throughput

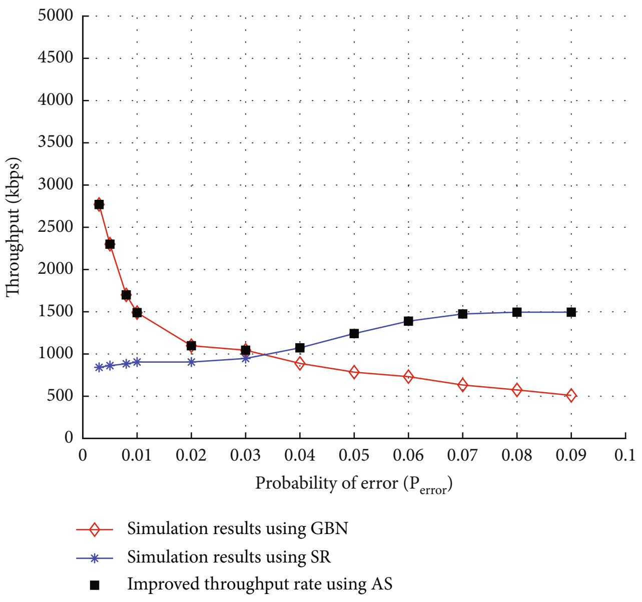


Figure 10: The evaluated simulation results under different packet loss rates for GBN, SR, and AS.

Table 3: The average amount of provided throughput improvement by the use of novel proposed AS method under different packet loss rates for GBN and SR.

	Mean throughput value (kbps)	Mean improvement W.R.T GBN	Mean improvement W.R.T SR
GBN	1219	0.00%	8.64%
SR	1122	-8.64%	0.00%
Proposed AS	1543	26.57%	37.52%

performance than SR for less P_{error} values and SR provide better performance for greater P_{error} values.

At this point, the value of P_{error} at the intersection point of throughput graphs in Figure 9 will be the crucial P_{error} value. Since the main goal of the work is maximizing the throughput performance, it is proposed for the network to switch between these two methods when P_{error} rate of the system reaches to the obtained critical P_{error} value.

Figure 10 gives the evaluated results in Figure 9 for both SR and GBN and the throughput improved by the system by using novel proposed AS method. The P_{error} rate value that the proposed AS algorithm will switch between two ARQ algorithms is also seen in Figures 9 and 10 as $P_{\text{error}} = 0.035$ where the result graphs evaluated by MATLAB simulation for GBN and SR intersect.

Since the system will periodically be aware of the packet error rates at each instance, it just decides whether the current P_{error} rate value is less than evaluated intersection point $P_{\text{error}} = 0.035\%$ or not, for switching from GBN to SR ($P_{\text{error}} < 0.035\%$) or for switching from SR to GBN ($P_{\text{error}} > 0.035\%$). The system will intentionally and periodically transmit packets using SR for a period and then using GBN for the same period while keeping the records of P_{error} rates vs. throughput to find and update the intersection point (P_{error} threshold).

The average amount of provided throughput improvement by the use of novel proposed AS method under different packet loss rates for GBN and SR is summarized in Table 3.

4. Conclusion and Discussion

In this work, the SDN structure integrated into an Internet of Health Things (IoHT) paradigm for the hospital environment is proposed and designed. Then, a novel proposed adaptive access technique called adaptive switching (AS) and based on traditional Go-Back-N and Selective Repeat technique is proposed.

Finally, the throughput performance of the proposed AS method is compared with the performances of traditional Go-Back-N and Selective Repeat ARQ methods using the developed MATLAB simulation. For this, an optimal P_{error} rate that the network should prefer to switch either from Go-Back-N to Selective Repeat or from Selective Repeat to Go-Back-N method to maximize the network throughput performance is determined. The evaluated results are also confirmed by theoretical calculation results using well-known Mathis throughput formula. It is shown by the evaluated results that when the novel proposed adaptive switching (AS) method is used, the throughput always has its best possible results for all P_{error} rates. Finally, it is being observed from Figure 10 and Table 3 that up to 37.52% throughput improvement is provided by the use of novel proposed adaptive switching (AS) method.

We will examine the performance of the suggested technique in future research by including different properties and critics data in the network, and add to that, we will include the energy factor to overall performance.

Data Availability

All data are available within the manuscript.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

References

[1] A. Lakhan, M. A. Mohammed, J. Nedoma et al., "Federated-learning based privacy preservation and fraud-enabled blockchain IoMT system for healthcare," in *IEEE Journal of Biomedical and Health Informatics*, 2022.

[2] N. Zahid, A. H. Sodhro, U. R. Kamboh et al., "AI-driven adaptive reliable and sustainable approach for Internet of Things enabled healthcare system," *Mathematical Biosciences and Engineering*, vol. 19, no. 4, pp. 3953–3971, 2022.

[3] H. B. Mahajan, A. S. Rashid, A. A. Junnarkar et al., "Integration of Healthcare 4.0 and blockchain into secure cloud-based electronic health records systems," in *Applied Nanoscience*, pp. 1–14, Springer, 2022.

[4] D. A. Hammood, H. A. Rahim, A. Alkhayyat, and R. B. Ahmad, "Duty cycle optimization using game theory two

master nodes cooperative protocol in WBAN," *Wireless Personal Communications*, vol. 122, no. 3, pp. 2479–2504, 2022.

[5] S. Nandy, M. Adhikari, S. Chakraborty, A. Alkhayyat, and N. Kumar, "IBoNN: intelligent agent-based Internet of medical things framework for detecting brain response from electroencephalography signal using bag-of-neural network," *Future Generation Computer Systems*, vol. 130, pp. 241–252, 2022.

[6] M. Y. Mehmood, A. Oad, M. Abrar et al., "Edge computing for IoT-enabled smart grid," *Security And Communication Networks*, vol. 2021, Article ID 5524025, 16 pages, 2021.

[7] S. Razdan and S. Sharma, "Internet of medical things (IoMT): overview, emerging technologies, and case studies," in *IETE Technical Review*, Taylor & Francis, 2021.

[8] D. A. Hammood, H. A Rahim, R. B. Ahmad et al., "Enhancement of the duty cycle cooperative medium access control for wireless body area networks," *IEEE Access*, vol. 7, pp. 3348–3359, 2019.

[9] S. Bera, S. Misra, S. K. Roy, and M. S. Obaidat, "Soft-WSN: software-defined WSN management system for IoT applications," *IEEE Systems Journal*, vol. 12, no. 3, pp. 2074–2081, 2016.

[10] M. Cicioğlu and A. Çalhan, "SDN-based wireless body area network routing algorithm for healthcare architecture," *ETRI Journal*, vol. 41, no. 4, pp. 452–464, 2019.

[11] K. Hasan, X. W. Wu, K. Biswas, and K. Ahmed, "A novel framework for software defined wireless body area network," in *2018 8th International conference on intelligent systems, modelling and simulation (ISMS)*, pp. 114–119, IEEE, Kuala Lumpur, Malaysia, 2018, May.

[12] T. M. Li, C. C. Liao, H. H. Cho, W. C. Chien, C. F. Lai, and H. C. Chao, "An e-healthcare sensor network load-balancing scheme using SDN-SFC," in *2017 IEEE 19th international conference on e-health networking, applications and services (Healthcom)*, pp. 1–4, Dalian, China, Oct. 2017.

[13] M. Al Shayokh, J. W. Kim, and S. Y. Shin, "Cloud based software defined wireless body area networks architecture for virtual hospital," in *Proceedings of the 10th EAI International Conference on Body Area Networks*, pp. 92–95, Sydney, Australia, Sept. 2015.

[14] L. Hu, M. Qiu, J. Song, M. S. Hossain, and A. Ghoneim, "Software defined healthcare networks," *IEEE Wireless Communications*, vol. 22, no. 6, pp. 67–75, 2015.

[15] K. H. Yeh, "A secure IoT-based healthcare system with body sensor networks," *IEEE Access*, vol. 4, pp. 10288–10299, 2016.

[16] F. A. Kraemer, A. E. Braten, N. Tamkittikhun, and D. Palma, "Fog computing in healthcare–a review and discussion," *IEEE Access*, vol. 5, pp. 9206–9222, 2017.

[17] M. Ghamari, B. Janko, R. Sherratt, W. Harwin, R. Piechockic, and C. Soltanpur, "A survey on wireless body area networks for ehealthcare systems in residential environments," *Sensors*, vol. 16, no. 6, p. 831, 2016.

[18] R. M. Madhumathi, A. Jagadeesan, and S. Kaushik, "Healthcare monitoring system using body sensor network," in *Proceedings of the International Conference on Engineering Innovations and Solutions (ICEIS-2016)*, pp. 171–176, Rome, Italy, 2016.

[19] S. R. Moosavi, T. N. Gia, E. Nigussie et al., "End-to-end security scheme for mobility enabled healthcare Internet of Things," *Future Generation Computer Systems.*, vol. 64, pp. 108–124, 2016.

[20] Y. I. Yuehong, Y. Zeng, X. Chen, and Y. Fan, "The Internet of Things in healthcare: an overview," *Journal of Industrial Information Integration*, vol. 1, pp. 3–13, 2016.

[21] T. Wu, F. Wu, J. M. Redouté, and M. R. Yuce, "An autonomous wireless body area network implementation towards IoT connected healthcare applications," *IEEE Access*, vol. 5, pp. 11413–11422, 2017.

[22] L. Catarinucci, D. De Donno, L. Mainetti et al., "An IoT-aware architecture for smart healthcare systems," *IEEE Internet of Things Journal*, vol. 2, no. 6, pp. 515–526, 2015.

[23] X. Chen, M. Ma, and A. Liu, "Dynamic power management and adaptive packet size selection for IoT in e-healthcare," *Computers & Electrical Engineering*, vol. 65, pp. 357–375, 2018.

[24] S. Jabbar, F. Ullah, S. Khalid, M. Khan, and K. Han, "Semantic interoperability in heterogeneous IoT infrastructure for healthcare," *Wireless Communications and Mobile Computing*, vol. 2017, 10 pages, 2017.

[25] A. Darwish, A. E. Hassanien, M. Elhoseny, A. K. Sangaiah, and K. Muhammad, "The impact of the hybrid platform of internet of things and cloud computing on healthcare systems: opportunities, challenges, and open problems," *Journal of Ambient Intelligence and Humanized Computing*, vol. 10, no. 10, pp. 4151–4166, 2019.

[26] E. Luo, M. Z. Bhuiyan, G. Wang, M. A. Rahman, J. Wu, and M. Atiquzzaman, "Privacyprotector: privacy-protected patient data collection in IoT-based healthcare systems," *IEEE Communications Magazine*, vol. 56, no. 2, pp. 163–168, 2018.

[27] F. Ali, S. R. Islam, D. Kwak et al., "Type-2 fuzzy ontology–aided recommendation systems for IoT–based healthcare," *Computer Communications*, vol. 119, pp. 138–155, 2018.

[28] A. Ahmed, M. S. M. Thabit, A. Alkhayyat, and Q. H. Abbasi, "Energy harvesting Internet of Things health-based paradigm: towards outage probability reduction through inter–wireless body area network cooperation," *International Journal of Distributed Sensor Networks*, vol. 15, no. 10, Article ID 155014771987987, 2019.

[29] A. Alkhayyat, A. A. Thabit, F. A. Al-Mayali, and Q. H. Abbasi, "WBSN in IoT health-based application: toward delay and energy consumption minimization," *Journal of Sensors*, vol. 2019, 14 pages, 2019.

[30] I. Marsic, *Computer networks: performance and quality of service*, Rutgers, New Jersey, 2013.

[31] X. Yi and W. Wanye, "Finding the fastest path in wireless networks," in *2008 IEEE International Conference on Communications*, pp. 3188–3192, Beijing-China, 2008.

[32] T. Slattery, "TCP performance and the Mathis equation," 2009, https://www.netcraftsmen.com/tcp-performance-and-the-mathis-equation/.

[33] "Validating a very simple model for TCP throughput," 2013, https://www.thousandeyes.com/blog/a-very-simple-model-for-tcp-throughput/.