International Journal of Electrical and Computer Engineering (IJECE)
Vol. 10, No. 1, February 2020, pp. 427~437
ISSN: 2088-8708, DOI: 10.11591/ijece.v10i1.pp427-437

Optimal packet routing for wireless body area network using software defined network to handle medical emergency

B. Manickavasagam[1], B. Amutha[2], S. Priyanka[3]
[1,2]SDC Testbed Laboratory, Department of Computer Science and Engineering,
SRM Institute of Science and Technology, India
[1,2,3]Department of Computer Science and Engineering, School of Computing,
SRM Institute of Science and Technology, India

Article Info

Article history:

Received Feb 17, 2019
Revised Apr 24, 2019
Accepted Jul 17, 2019

Keywords:

Critical packet forwarding
Modified greedy approach
Optimal packet routing
Packet prioritization
Wireless body area network

ABSTRACT

The packet forwarding node selection is one of the main constraints in the Software Defined Network (SDN). To improve the network performance, the SDN controller has to choose the shortest and optimized path between source and destination in routine and emergency packet transmission. In e-health service, information of the emergency patient has to be transferred immediately to remote hospitals or doctors by using efficient packet routing approach in Wireless Body Area Network (WBAN). In WBAN, to improve the packet transmission, the optimal packet routing policy developed based on packets priority with the support of a greedy algorithm for SDN. The SDN Controller selects the forwarding node based on node propagation delay and available bandwidth between two forwarding nodes. The mesh network topology network created for implementation, implementation results are compared with existing research works. Finally, this algorithm implemented in our institution, Software defined communication testbed laboratory (SDCTestbed Lab) with the support of 13 Zodiac-Fx (Forwarding device), 2 Raspberry-Pi3 B+ Model (host) and Arduino kit (sensor node).

Corresponding Author:

B. Manickavasagam,
SDC Testbed Lab, Department of Computer Science and Engineering,
SRM Institute of Science and Technology,
SRM Nagar, Kattankulathur Post, Kanchipuram District, Tamil Nadu, 603203-India.
Email: bmanickavasagam90@gmail.com

1. INTRODUCTION

Wireless Sensor Node (WSN) is a combination of small electrical components and which are all performing some specific task in the environment with the help of a micro - level processor, a sensing component, a small quantity of memory and low frequency and low range wireless transceivers (less than a meter). Now a day's WSNodes have used in many fields (like a battlefield [1], Remote Sensing Area [2], Agriculture [3], industries [4-6] and medical fields [5]). Wireless sensor nodes are providing endless supports for a medical field compared with other applications. In medical, sensor node acquires the vital signals from patients and transmit that into remote physician's digital assistant (PDA) in a real-time or delayed approach. Not only that, some sensor components predicts the abnormal of health in advance and warns the caring person to avoid the risk.

During the communication sensor node and its components are transmitting information over a medium using different standards in different stages, see Figure 1. Stage-1 multiple sensor nodes acquire the physiological signal from the body and communicate to one single point gateway using near field communication or short-range transmission mechanism. In stage-2 information are transmitted from a single point gateway to nearest access point or hub using medium rage range communication, the communication range will be less than 100 meters. An access point transmits the gathered information to a hospital or doctor's PDA over a wired or wireless medium using long range communication standards in stage-3.

In a WBAN network, the wireless sensor nodes are(which placed in the human body or on the human body) transmits the acquired patient's health signals to the wireless sensor node coordinator (WSNC). The WSNC collects the vital information of the patient from different Wireless Sensor Nodes (WSNode) that all have attached on or in the human body, see Figure 2. Compare with WSNodes; a WSNC node has more energy resource, processing capability and medium-range transceiver. WSNC processes the data based on the patient 's health history; it categorises the priority level of information for faster transmission using medium-range and long-range communication and for quick diagnosis. In my previous research work, we explained dynamic bandwidth allocation for critical patients in a wireless interface for medium range communication (Tire-2).

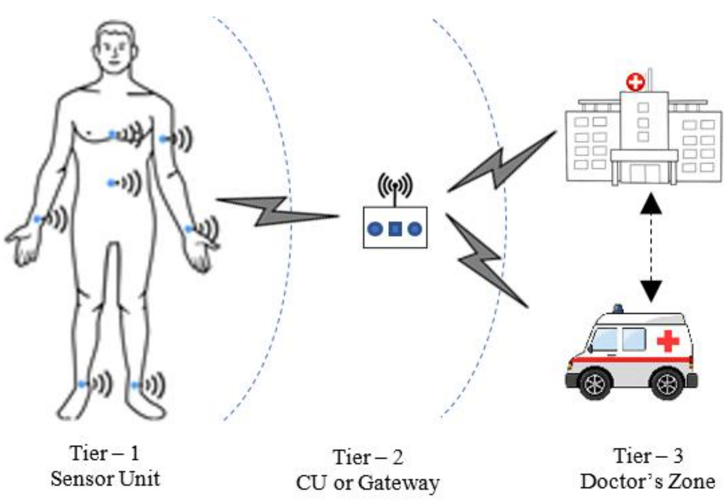

Figure 1. 3-tire healthcare service architecture

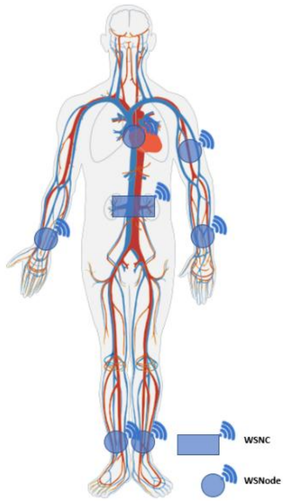

Figure 2. Wireless body area network

The tire-3 topology handles a large amount of data from heterogeneous devices compared with short-range and medium-range communication topology. This network information is managed and periodically updated to entire devices among the network by centralised [7] or distributed manner. During the data update, the large amount of packet transmitted between network components, and it leads to the poor quality of services (QoS). Not only that, if the updates happen in a distributed approach, then each intermediate devices handle the packet forwarding and network management, it leads to a bottleneck problem.

Nowadays most of the networks are utilising the SDN abstract in a different network environment. SDN separates the network control and data plane, and it manages all the network control planes in a centralised location. Through this approach, all the intermediate devices are only handling the packet forwarding that means, it merely receives the packet from the source node and transmit those to the destination node based on rules. The controller performs the packet preprocessing tasks, decision-making among the packets; then the instruction passed to a particular forwarding device to initiate the packet forwarding. Through this approach, we can reduce the forwarding node bottleneck problem, computational cost, and network information update and management cost. In SDN, controller node computes the optimised or efficient flow path between a source and destination nodes. SDN network maximum used in data center network to optimize the load balance between the network [8]. To choose the efficient path different strategies are handled by controller especially node weight model, in this model controller assigns the weight or priority values for each communication link. Using this weight controller selects an efficient flow path for packet transmission, but there is a problem to choose the route using a single weight value. Because, if shorter distance network path occupied by maximum no of nodes its lead to high packet error rate or high traffic. To resolve this issue, we developed the optimal packet routing using multiple paraments to handle the medical emergency packets with the support of SDN features. Based on the research objective we studied some existing research work and its future enhancement information.

2. LITERATURE REVIEW

WSNC receives the different sensor node information at different timing interval, and this information is transmitted to the Pre Transmission Evaluation (PTE) process. After PTE, WSNC identifies the critical information controller to initiate the fast forwarding and process controller forwards the packets in the quickest and shortest route. To predict the fast packet transmission path, several researchers developed various routing algorithms [9-11].

A greedy algorithm is a problem-solving technique, in each stage, it finds optimal choice based upon local condition, and finally, it leads to global optimisation. Most networking algorithms are utilising the greedy approach, Like Minimum Spanning Tree (MST) [12], Travelling Salesman Problem (TSP) and few more. The edge value based each network vertices selected it's called as a weight of the edge. Using this edge value, the Dijkstra applies some condition to choose the next vertices. It finds the local solution in each stage, and it leads to the global optimised result. In this approach, the optimal path node selected using one parameter edge weight. However, network packet transmission depends upon multiple parameters, like delay [13], energy consumption [14-20], Bandwidth, Data Rate [21], Traffic [22- 24], Travelling cost and Link Quality [25].

Using one parameter can't say we have achieved the optimal path between source and destination. To resolve this above problem, in [26], A. Bozyiğit, G. Alankuş and E. Nasiboğlu, proposed a modified Dijkstra's algorithm and it is implemented in a real-world public transport network. In this approach, the author assigned some negative value for each path and found the alternate road to achieve a good result. To improve the optimal path selection, we propose an Optimized Packet Routing approach in this paper.

3. OPTIMIZED PACKET ROUTING

WSNC or Controller choose an optimal and efficient route path between WSNC and server or sink. To select the optimal way, the controller follows a greedy strategy and this path selection algorithm divided into three stages, which are:

a. Threshold classification
b. Stage classification
c. Node selection

Controller finds a Threshold level for the weights using Threshold Classifier. After the Threshold level calculation controller moves to the stage classification algorithm. In that, depending upon the Threshold level, the controller drives the stage level. Finally, the controller will design a Node selection algorithm using stage classification result.

3.1. Optimised path selection

The controller uses the Greedy approach to select the optimised paths between source and destination based on two different node weights which are Node delay (W1) and Link Bandwidth (W2). Node packet priority based controller derives the policy to choose the flow path between sources to destination using node weights.

3.1.1. Node selection process

First, the controller analyses the number of available nodes in the network and its direct communication link to another node; then, it calculates the total values of weight1 (TW1), it's average (AW1), and percentage level of TW1 (PW1). Similarly, it finds the total (TW2), Average (AW2), Percentage (PW2) of weight2 and so on for all nodes. Weight1:

$$TW_1 = \sum_{i=1}^{N} W_{1i} \quad (1)$$

$$AW_1 = \frac{TW_1}{N} \quad (or) \quad \frac{\sum_{i=1}^{N} W_{1i}}{N} \quad (2)$$

Using (1), $PW_1 = \frac{TW_1}{100}$ (3)

Similarly, Weight2:

$$TW_2 = \sum_{i=1}^{N} W_{2i} \quad (4)$$

$$AW2 = \frac{TW2}{N} \quad (or) \quad \frac{\sum_{i=1}^{N} W_i}{N} \quad (5)$$

$$PW = \frac{TW2}{100} \quad (6)$$

By using (3) and (6), controller checks the weight of visiting node(VW_1), a weight percentage of visiting node (VPW_1) and finds the average of visiting node weight percentage ($AVPW_1$) similarly VPW_2.

$$VW1_j = W1_{(i,j)} + W1_{(i)} \tag{7}$$

$$VW2_j = W2_{(i,j)} + W2_{(i)} \tag{8}$$

$$AVPW1_j = \frac{VPW1_j}{Visiting\_Node\_Level\ (NL)} \tag{9}$$

$$AVPW2_j = \frac{VPW2_j}{Visiting\_Node\_Level\ (NL)} \tag{10}$$

where, visiting_Node_Level is the number of hop count to reach the visiting node from the source node.

$$VPW_i = PW_i \times W_i$$

Depending upon the patient condition: either normal or abnormal, the node selection condition will change. Now the controller uses the Optimized Packet Routing algorithm using selection policy.

3.2. Threshold classification

The controller drives the node selection using the threshold value of weight by using the Threshold Classification algorithm (Alg. 3.1). In this, the controller finds the Threshold value by using Average Node weight value and node priority value.

Algorithm 3.1: Threshold_ Classification()

Input: Average_Weight (AW), Total_Priority_Level(N)
Output: Threshold_Level$_{(N)}$
Initialization: initital_value=1;
Loop: Check initial_value is less than or Equal N

$$Threshold\_Level_{(ThW_i)} = \frac{AW \times [N - (N - i)]}{N}$$

Increment initial_value
End // loop End
End // algorithm End

3.3. Stage classification

In this stage classification, the controller uses the threshold value and visiting node's weight percentage value and total priority level.

Algorithm 8.2: Stage_Classification()

Input: Threshold_Level(ThW_N), Visiting_Node_Weight_Percentage (VPW), Total_Priority_Level(N)
Output: (N+1) Stage classification result (SL_{N+1})
Initialization: Initial_value=1;
ThW=Threshold_Classifiction();
Loop: Initial_value less than or equal N
    If Initial_value =1
        Set: $SL_{Initial\_value}$ is VPW ≤ $ThW_{Initial\_value}$;
    Else If Initial_value is N
        Set: $SL_{Initial\_value}$ is VPW>ThW_{N-1} && VPW ≤ ThW_N;
    Else If Initial_value more than 1 && not N
        Set $SL_{Initial\_value}$ is VPW>$ThW_{Initial\_value-1}$ && VPW ≤ $ThW_{Initial\_value}$
    End If
    Increment Initial_value;
End Loop
Set: $SL_{Initial\_value+1}$ is VPW >$ThW_{Initial\_value}$
End Algorithm

3.4. Node selection algorithm

Node selection algorithm (Algorithm 3.3) is a final step in the Optimized Packet Routing algorithm. In this, the controller selects the efficient forwarding nodes between source and destination using threshold and stage classification algorithm. The node Selection algorithm is given below.

```
Algorithm 3.3: Node_selection()
    Input: Visiting_Node_Weight_Percentage (VPW), Stage_Classifier_Values (SL_{N+1}),
    PRIORITY_Level (PL_i), Graph_Vertices (V), Graph_Weight(W1,W2),
    Output: select the optimal and efficeint forwarding node.
    Initialization: i=1,j=1,k=1;
    SL=Stage_Classification();
    If V_i, not Source and destination node
        If PL is "Normal"
            If V_i(VPW1) is SL_j and V_(i+1)(VPW1) is SL_(j)
                If V_i(VPW2) is more than SL_j
                    Select V_i
                Else
                    Select V_j
                End
            Else if V_i(VPW1) is SL_j and V_(i+1)(VPW1) is SL_(j+1)
                If V_i+1(VPW2) is more than SL_j+2
                    Select V_i+1
                Else
                    Select V_i
                End
            Else if V_i(VPW1) is SL_j and V_(i+1)(VPW1) is SL_(j+2)
                If V_i+1(VPW2) is more than SL_N
                    Select V_i+1
                Else
                    Select V_i
                End
            End
        Else if is "abnormal."
            If V_i(VPW1) is SL_j and V_(i+1)(VPW1) is SL_(j)
                If V_i(VPW2) is less than or SL_j
                    Select V_i
                Else if V_i(VPW2) is
                    Select V_j
                End
            Else if V_i(VPW1) is SL_j and V_(i+1)(VPW1) is SL_(j+1)
                If V_i+1(VPW2) is less than SL_j+2
                    Select V_i+1
                Else
                    Select V_i
                End
            Else if V_i(VPW1) is SL_j and V_(i+1)(VPW1) is SL_(j+2)
                If V_i+1(VPW2) is less than SL_N
                    Select V_i+1
                Else
                    Select V_i
                End
            End
        End
    End
```

```
Algorithm 3.4: Optimized_Packet_Routing_Algorithm ()
Initialise_source ( Graph gr, Node s, Node d )
  for each vertex v in Vertices( gr )
     gr.dis[v] := infinity
     gr.pi[v] := nil
  gr.dis[s] := 0;
TW:= Total_Weight, AW:=Average_Weight, PW:= Average_Weight_Percentage;

Modified_dijkstra( Graph gr, Node s, Node d , Weight W1, Weight W2, )
   initialise_source ( gr, s,d )
   V := { 0 }      /* Make visited node empty */
   Q := Vertices( gr ) /* initially put all non-visited nodes in Q */
   while Q is not empty
      u := Extract( Q );
      AddNode( V, u ); /* Add u to S */
      for each vertex v in Adjacent( u )
         Node_selection( V,u,v)
```

4. IMPLEMENTATION

Controller analyses the Trust Value and depends upon trust value; it selects the forwarding node using Routing_Algorithm_with_Multiple_Parameters (delay and bandwidth).

Test case details:

Total no of wireless switches or nodes - 6 Nos, Total no of links between switches - 9 Nos, weight1(W1) is node delay its units are in seconds, weight2 (W2) is available link bandwidth two forwarding nodes, its unit measurement is Mbps, Communication medium: Fast Ethernet at maximum of 100 Mbps transfer rate. Figure 2, describes the optimised packet routing algorithm in each level.

4.1. Stage 0

Figure 2(a) describes the Initial Stage s*et al*l the node values are infinity, Select the source and a destination node, identify the no of edges, and calculate TW1, AW1, PW1, similarly weight2,

a. N = 9;
b. TW1 = 58 & AW1=6.4 & PW1=0.58
c. TW2=85 & AW2=9.4 & PW2=0.85
d. ThW1= 2.13
e. ThW2= 3.13
f. S1 to s6 are forwarding devices
g. W1, W2 is delay and bandwidth
h. Source S1; Destination S6
i. Source ≠ Destination (S1≠S6)

4.2. Stage 1

Figure 2(b) explain the stage1 process. Here, the controller set source node weight is zero, and the remaining node weight is infinity. Below.

a. Set S1weight (0,0)
b. Set weight as Infinity for remaining nodes

4.3. Stage 2

In Figure 2(c), the controller selects the next hop forwarding node from node S1, and it's details are,
Apply node selection condition
From S1 to S2:
VW_{S2}=0+5=5; 0+10=10;(5,10)
$VPW1_{S2}$=2.9, $VPW2_{S2}$= 8.5 (2.9,8.5)
S2 values are added in the table but not selected for forwarding.
From S1 to S3:
VWS3=0+7=7; 0+18=18;(7,18)
VPW1S3=4.06, VPW2S3=15.3 (4.06,15.30)
Select S3 (4.06,15.30), because $VPW1_{S1}$ && $VPW1_{S3}$ in a same category then, controller select the 'S3' as a forwarding node and visited node.

4.4. Stage 3

In stage controller selects the next forwarding node, the details are explained below and selected node shown in Figure 2(d).

Source of S2: 2.9,8.5 (as per stage 2)
From S3 to S2:
Source of S2: 2.9,8.5 (as per stage 2)
Now,
$VW_{S2}=(W1_{(S3,S2)},W2_{(S3,S2)}) + (W1_{(S3)},W2_{(S3)})$
$VW_{S2}=(15,24)$
$VPW1_{S2}=4.35$, $VPW2_{S2}=10.2$ (4.35,10.2)
New VPW1 and old VPW1 both are in the same condition. New VPW2 is greater than old VPW2. So, we are selected S2 as a visited node and selected for forwarding.
From S3 to S5:
$VW_{S5}=(W1_{(S3,S5)},W2_{(S3,S5)}) + (W1_{(S3)},W2_{(S3)})$
$VW_{S5}=(11,20)$
$VPW1_{S5}=3.19$, $VPW2_{S3}= 8.5$ (3.19,8.5)
VPW1 is in 2stage also VPW2 < AW1, for this reason, it is still in visiting node and its values added in table

4.5. Stage 4

Figure 2(e), describes the node selection process from Node S3 and its process are explained below,
From S3 to S4:
$VW_{S4}=(W1_{(S2,S4)},W2_{(S2,S4)}) + (W1_{(S2)},W2_{(S2)})$
$VW_{S4}=(19,39)$
$VPW1_{S4}=3.67$, $VPW2_{S4}=11.05$ (3.67,11.05)
Comparing S4 and S5, both are in the same stage but, S4 has low VPW1 and High bandwidth. So the controller selects the S4 as a visited node and forwarding device.
From S3 to S5:
Source of S5: 3.19,8.5 (as per stage 3)
$VW_{S5}=(W1_{(S2,S5)},W2_{(S2,S5)}) + (W1_{(S2)},W2_{(S2)})$
$VW_{S5}=(21,36)$
$VPW1_{S5}=4.06$, $VPW2_{S3}= 10.2$ (4.06,10.2)
New VPW1 and Old VPW1 both are in the same stage, but New VPW2 is greater than old VPW2 and AW2. For this controller removes the existing info from table and added the new info. Note: still S5 in visiting node

4.6. Stage 5

The controller selects the next forwarding node of S4 and details are explained in Figure 2(f).
From S4 to S6:
VWS6=(W1(S4,S6),W2(S4,S6)) + (W1(S4),W2(S4))
VWS6=(19,39)
VPW1S6=4.20, VPW2S6=9.98 (4.20,9.98)
VPW1 of s6 stage 2 and its VPW2 is greater than AV. So controller set the S6 as a visited node.
Note: Here, controller not stopped the node selection process because from S4 has another one direct connection.
From S4 to S5:
Source of S5: 4.06,10.2(as per stage 4)
VWS5=(W1(S4,S5),W2(S4,S5)) + (W1(S4),W2(S4))
VWS5=(28,47)
VPW1S5=4.06, VPW2S3= 9.98 (4.06,9.98)
New VPW1 equal to Old VPW1 and New VPW2 is less than the Old one. So the controller selected the existing value. And S6 changed into the visited node.

4.7. Stage 6

To S6:
Source of S5: 4.06,10.2(as per stage 4)
$VW_{S6}=(W1_{(S5,S6)},W2_{(S5,S6)}) + (W1_{(S5)},W2_{(S5)})$
$VW_{S5}=(26,42)$
$VPW1_{S5}=3.77$, $VPW2_{S3}= 7.65$ (3.77, 7.65)
Here New VPW1 is less than Old VPW2 and same stage, but new VPW2 is less than Old VPW2, also its lower than AW2.

So, the controller selects the Existing value of S6 (Figure 2(f) and (g)), the Finally, controller selects the path from source node S1 to destination node S6, and it forwards the information using S1 – S3 – S2 – S4 – S6 with a total delay of 29 and bandwidth of 47 for standard packet transmission.

4.8. Stage 7

The controller selects the same algorithm to select the route between source and destination during critical packet transmission as shwon in Figure 2(h). Finally, Table 1 describes the packet flow information and Table 2 contains the final flow result value of Critical packet transmission.

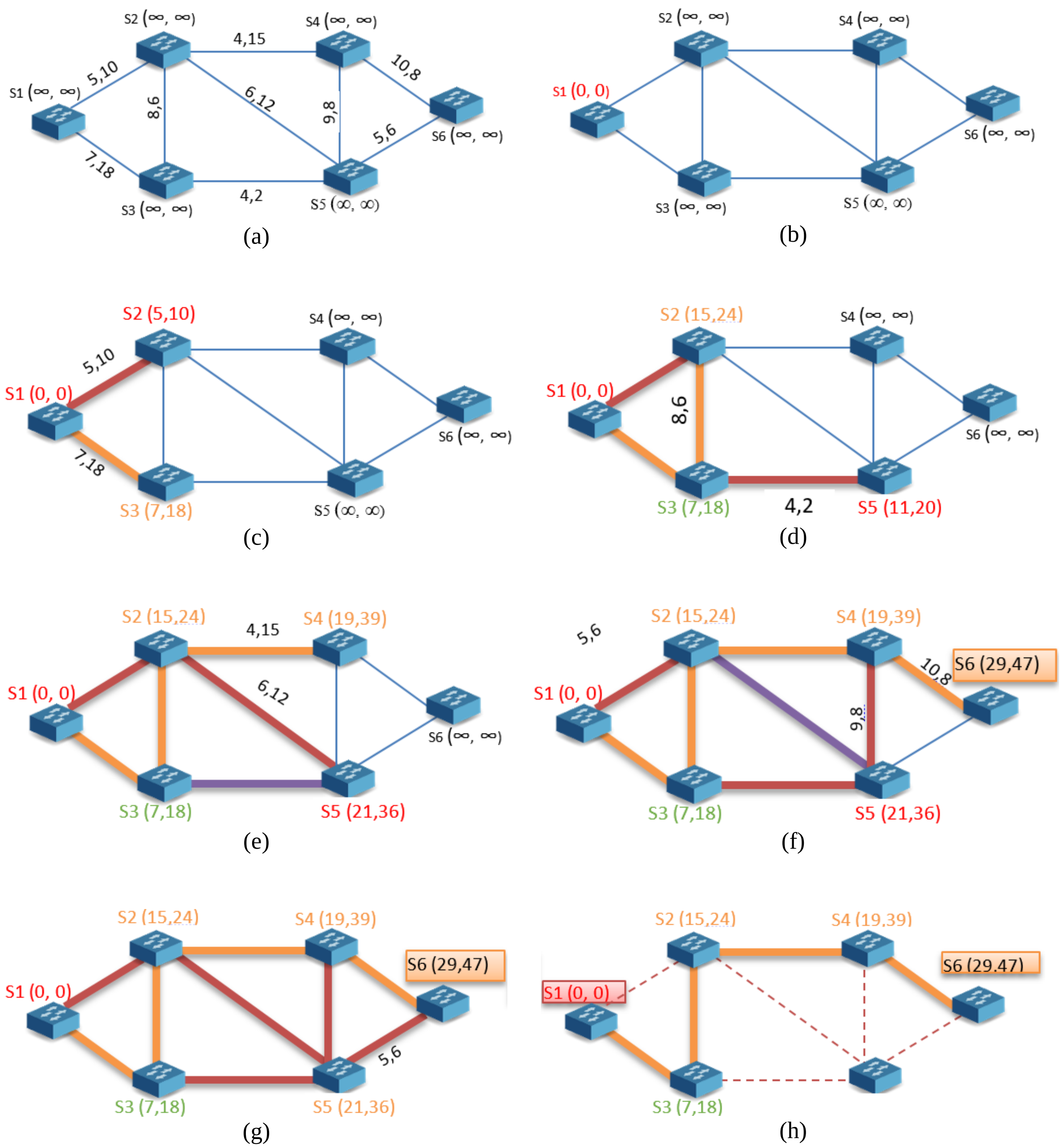

Figure 2. Optimized routing algorithm stage wise procedure, ((a-g) normal packet transmission. (h) Optimal path for emergency state); (a) Stage 0: Nodes and its connections are represented in Graph form, (b) Stage 1: Source node selection, (c) Stage 2 Optimal path algorithm, (d) Stage 3 Optimal path algorithm, (e) Stage 4 Optimal path algorithm, (f) Stage 5 Optimal path algorithm, (g) Stage 6 Optimal path algorithm, (h) Optimal path selection in emergency

Table 1. Flow table details of optimal packet routing algorithm in stage wise

	-	S1	S2	S3	S4	S5	S6
Stage 1	S1	0,0	∞, ∞	∞, ∞	∞, ∞	∞, ∞	∞, ∞
Stage 2	S1	0,0	5, 10	7, 18	∞, ∞	∞, ∞	∞, ∞
Stage 3	S1	0,0	5, 10	7, 18	∞, ∞	∞, ∞	∞, ∞
	S1	0,0	15, 24	7, 18	∞, ∞	11, 20	∞, ∞
Stage 4	S1	0,0	5, 10	7, 18	∞, ∞	∞, ∞	∞, ∞
	S1	0,0	15, 24	7, 18	∞, ∞	11, 20	∞, ∞
	S1	0,0	15, 24	7, 18	19, 39	21, 36	∞, ∞
Stage 5	S1	0,0	5, 10	7, 18	∞, ∞	∞, ∞	∞, ∞
	S1	0,0	15, 24	7, 18	∞, ∞	11, 20	∞, ∞
	S1	0,0	15, 24	7, 18	19, 39	21, 36	∞, ∞
	S1	0,0	15, 24	7, 18	19, 39	21, 36	29, 47
Stage 6	S1	0,0	5, 10	7, 18	∞, ∞	∞, ∞	∞, ∞
	S1	0,0	15, 24	7, 18	∞, ∞	11, 20	∞, ∞
	S1	0,0	15, 24	7, 18	19, 39	21, 36	∞, ∞
	S1	0,0	15, 24	7, 18	19, 39	21, 36	29, 47
	S1	0,0	15, 24	7, 18	19, 39	21, 36	29, 47
Stage 7	S1	0,0	5, 10	7, 18	∞, ∞	∞, ∞	∞, ∞
	S1	0,0	15, 24	7, 18	∞, ∞	11, 20	∞, ∞
	S1	0,0	15, 24	7, 18	19, 39	21, 36	∞, ∞
	S1	0,0	15, 24	7, 18	19, 39	21, 36	29, 47
	S1	0,0	15, 24	7, 18	19, 39	21, 36	29, 47

Table 2. Final flow result of critical packet transmission

-	S1	S2	S3	S4	S5	S6
S1	0,0	5, 10	7, 18	∞, ∞	∞, ∞	∞, ∞
S1	0,0	5, 10	7, 18	∞, ∞	11, 20	∞, ∞
S1	0,0	5, 10	7, 18	10, 25	11, 22	∞, ∞
S1	0,0	5, 10	7, 18	10, 25	11, 22	20, 33

5. PERFORMANE ANALYSIS

In this optimal packet routing algorithm compared with modified dijksta's algorithm for this we utilized 13 forwarding nodes and ech time we modified the edges for the vertices. Finally the processing time of algorithm analysed, the processing thime comparisson details are shown in Figure 3.

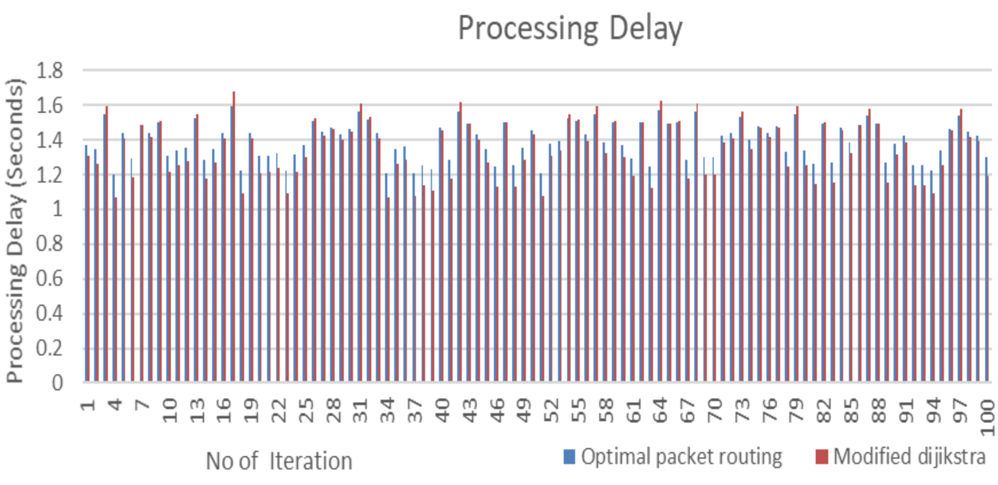

Figure 3. Processing time for modified and optimal packe*t al*gorithm

6. CONCLUTION AND FUTURE ENHANCEMENT

In this research work we find the Optimized packet routing algorithm through this SDN controller selects the Path between source and destination using combination of node delay and available medium bandwidth. And test case we explained the both critical and normal packet transmission procedures. In this we didn't explain the utilization of average bandwidth requirement of critical packet transmission and packet transmission rate.

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BIOGRAPHIES OF AUTHORS

Manickavasagam Balasubramanian, Member of IEEE, was born on 09th March 1990 in Thanjavur, Tamil Nadu. He obtained his Diploma in Computer Technology in 2008 from Pattukkottai Polytechnic College, later he completed Bachelor of Engineering in Apollo engineering College, Affiliated to Anna University, then Master of Technology, SRM University in the year of 2011 and 2014 respectively under Computer Science and Engineering. Currently, he is pursuing Doctor of Philosophy, in the domain of Software Defined Wireless Body Area Network. His research interests are Software Defined Network, Network Security, Sensor Networks, Internet Of Things. Mail ID: bmanickavasagam90@gmail.com

Amutha Balakrishnan was born on 07th June 1962, In 1994 she was completed her Bachelor degree in Instrumentation and Control Engineering in Annamalai University, In the year of 2002, she completed her Master of Engineering, in Computer Science and Engineering, Madras University. Later, in the year 2012, she received a Doctor of Philosophy degree from SRM University. Last two decades she had experience in teaching, from 2012 onwards she is working as a Head of the Department. SRM IST, Chennai, India. Her research Interest are Artificial Intelligence, Machine Learning, Sensor Network, Internet of Things, and Cooperative Computing. Mail Id: bamutha62@gmail.com

Priyanka Sudhakara was born on 1st June 1991 in Chennai, Tamilnadu, India. She obtained her Bachelor of Engineering (B.E.) Degree in Computer Science and Engineering (CSE) from the Sree Sastha Institute of Engineering and Technology, Affiliated to Anna University, Chennai and Master of Technology (M.Tech) Degree in Knowledge Engineering (CSE Specialization) from SRM University, Kattankulathur, Tamil Nadu in the years 2012 and 2014 respectively. She is currently working as Full-Time Research Scholar in School of Computing, SRM Institute of Science and Technology (Formerly SRM University), Kattankulathur, Tamil Nadu. Her research interests are Robotic Navigation, Artificial Intelligence techniques, Machine Learning algorithms, Soft Computing, Computer Vision, Wireless Sensor Networks, Internet Of Things, etc. Mail ID: miyu.priyanka@gmail.com