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SDN-Based Resource Reservation Protocol for IoT applications in Constrained Networks

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Abstract: Constrained netwrks like Wireless Sensor Networks have been identified as a promising scheme for next-generation wireless networks. These networks are capable of capturing data from the physical world without human intervention possessing applications such as IoT in various fields of life that require reliable and précised end to end delivery. However, Wireless Sensor Networks inevitably suffers from severe resource constraints and hence promising the provision of desired QoS is a challenge. In most of the applications like military, medical surveillance. Data captured are critical and hence the transmission of such data entails a minimal end to end delay. In constrained networks achieving minimal delay with effective utilization of resources are important cost factors for achieving an end to end delivery. In this Paper, a Software-defined Networking (SDN), based resource reservation protocol, which leverages SDN to centrally process the whole control logic and accordingly decides the amount of resources to be allocated for each data flow alleviating the processing overhead of all other nodes thus minimizing the energy consumption is proposed. The proposed algorithm is evaluated through simulation and the results obtained proved the efficiency of the proposed protocol by effectively minimizing the system's energy consumption and end to end delay.

***Index Terms*: Critical data, Energy utilization, Internet of Things, Resource reservation protocol, Software Defined Networks, Wireless Sensor Networks.**

I. INTRODUCTION

Recent developments in the field of electronics and technology have given birth to the new epoch of Internet of Things (IoT). The Internet of Things (IoT) is defined as a new paradigm in which objects equipped with sensors, actuators, and processors that possess omnipresent intelligence and communicate with each other to serve a significant purpose. IOT enables communications between objects around us, we are also witnessing a new way of communication happening between physical objects and human beings through the Internet[1]. Thus, IOT is enabling smarter and safer life with a myriad variety of applications which will become a part and parcel of human life. In such applications where data need to be collected from the physical environment without the intervention of human beings, wireless sensor networks play a pivotal role for data sources[2]. Wireless sensor networks (WSN) is a network of constrained devices called sensor nodes. These sensor nodes are responsible for capturing information from the physical environment in which these nodes are deployed[3]. Sensor nodes are constrained in its resources like memory, power, size, processing, and bandwidth. WSN has a varied and large number of applications in almost all fields of human life interactions. These applications have heterogeneous data to be sensed and transmitted with different QoS requirements. As some human life-saving applications require a infalliable and timely end to end delivery, the resource-constrained nature of WSN poses challenges to guarantee the required reliable, definitive and timely delivery of such application [4]. For reliable and timely delivery; resources need to be managed optimally along the path from the node until the data reaches the base station. The energy of each sensor node is constrained since it is battery operated and hence it needs to be optimally utilized so that end to end communication of critical data could be achieved reliably and within time. This can be accomplished by managing the resources efficiently and fairly by reserving the required resources along the path to the destination. Also, the efficiency of resource management and end-to-end QoS can be augmented by designing appropriate resource reservation mechanisms. Resource reservation in WSN is a demanding and challenging task as there is no prior information about event occurrences in future, reservations must be preserved in a confined environment and data may need to be transmitted periodically. Integrated Services is one such approach that aids to satisfy the needs of QoS-demanding applications. Applications convey their QoS requirements to the network efficiently and robustly by means of RSVP[5]. RSVP is the main component of the Integrated Services of Internet which provides best-effort and real-time service[6][7]. RSVP for traditional networks is a network control protocol specified in RFC 2205. RSVP does not provide any network service; it communicates the end-to-end system requirements to the network[8] permitting the receiver to appeal an end-to-end QoS for its data flows and reserving needed resources at routers along the path in real-time applications. All nodes in the data path must be RSVP compliance for an assured QoS. Resource reservation challenges of WSN are inherited from traditional wireless networks, such as time-varying channels and unreliable links along with characteristics of WSNs, such as severe resource constraints and harsh environmental conditions[6]. These Resource Reservation challenges for WSNs are discussed below:Resource constraints: WSNs are limited in resources such as bandwidth, memory, energy and processing capability.

Nevertheless, Energy is the

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biggest constraint as sensor nodes are equipped with unreplaceable batteries[9]. Energy consumption in sensor nodes is classified into three types i) Energy consumption in the transducer. ii) Energy consumption for communication among the sensor nodes iii) Energy consumption for microprocessor computation. The study by Hill et al[7] found that each bit transmitted in wireless sensor networks consumes power which is equivalent of power required to execute 800-1000 instruction. Hence Communication is costlier than computation in wireless sensor networks.

Memory Limitations: A sensor node is embedded with a small amount of memory such as flash memory and random-access memory thus once the operating system is loaded, execution of complicated algorithms is very challenging. Hence, a flexible and incremental resource management protocol needs to be designed without burdening the sensor node considering their power limitations. Multiple traffic types: WSN is deployed for sensing various data like scalar and multimedia data generating different traffic. Therefore, applications with multiple traffic classes which differ from each other in QoS adds extra challenging issues in managing and reserving these different resource requirements[10].

Real-time traffic: WSN has various acute applications like monitoring natural disaster and security surveillance, sensed data is valid only for a stipulated time frame and has to be delivered before its deadline. Administering this sort of information poses challenges in resource management and reservation.In order to address these challenges of WSN, research has been carried out, In [11] P. Javier and the team have proposed lightweight, flexible and adaptive resource management architecture. In this architecture, contextual information gathered from the network and service level architecture is used to manage the wireless sensor network resources. In [12] W.-H. Cho, J. Kim, and O. Song, have proposed resource management protocol that uses the resources of gateway or the server to increase the performance. Misra Sudip and his team have utilized context awareness for sharing information to control the network. To manage the energy of the network efficiently spatial and temporal correlation is being used [13]. In [13] authors have proposed a resource management scheme in a bottom-up approach. In this scheme sensor node is responsible for job selection using reinforcement learning. Stream authentication and unequal error protection are optimized by allocating resources to reduce image distortion and energy consumption. Wireless sensor devices are managed by using IPV6 on low power wireless personal area network and constrained application protocol [14]. In [15] authors have discussed resource management issues in WSN's, WLAN's and cognitive radio networks. They have considered energy minimization techniques based on explicit node cooperation and distributed source coding. Regini and Daesob have proposed a solution which includes scheduling and routing algorithms that reduce energy consumption and lowers latency [16]. In [17] authors have briefed about the background of SDN and its compatibility in WSN. SDN guaranteed content delivery with simplified network management and control over the devices. Musa and Ndiaye and others have focused on recent work on traditional WSN management and also discussed SDN-based techniques [18]. But none of these papers have worked on designing a protocol for resource reservation for constraint networks. There is no signaling protocol for Wireless Sensor Networks, and to the best of our knowledge, the existing signaling protocols like SIP/RSVP are not suitable for resource-constrained devices which are used in WSN. Hence, it is essential to design and develop a signaling protocol for optimal usage and efficient management of resources in constrained networks to achieve minimal end to end delay with desired QoS.

In recent times, software-defined networking (SDN) has materialized as a flexible and efficient alternative for data network management by decoupling the control and data planes. The SDN controller is software-based, and the entire network operation is derived from it. The control plane assists in making decisions about the forwarding path and resource allocation for a particular data flow. The forwarding plane abides the policies set by the control plane in forwarding the data packets. Compared with the conventional distributed network control mode, the centralized mode is potentially promising because controlling the network behavior becomes easier in this mode. SDN could be considered as a potential way to address reserving resources along the pathway from the end node to the base station[18][19]. In traditional Sensor networks, all nodes are responsible for processing and taking decisions about resource allocation leading to a lot of processing overheads [13].

In this paper, a novel resource reservation protocol is proposed employing the idea of SDN approach [SDN-RRP] to achieve reduced energy consumption and end to end delay with desired QoS. This approach keeps the entire network functionality at the central computing platform and making all the intermediate and end nodes lightweight in its processing. The goal of this reservation protocol is to provide mandated resources for transmission of sensed critical data that can save a human life if appropriate actions are taken immediately. The proposed protocol is implemented to run in the SDN based controller, which differs from a traditional approaches. Simulation results shows that the proposed SDN-RRP protocol achieves reduced energy consumption and delay with optimal resource utilization compared to current state of the existing approaches [[13,14 16 and [20]]. The remainder of this paper is organized as follows. Section II discusses the proposed work. Sections III briefs the results and discussions and Section IV concludes the paper.

II. RESOURCE RESERVATION PROTOCOL FOR WIRELESS SENSOR NETWORKS (RRP-WSN):

1.1 PROPOSED ARCHITECTURE:

The proposed network architecture considered in this work is a software-defined networking (SDN) based group of clusters deployed in various layers as shown in Figure.1. The proposed architecture consists of *L* levels consisting of *C* clusters; each cluster consists of *s* sensor nodes in it. Each sensor node is equipped with the Local controller (LC) to sense and forward the data and each cluster is equipped with the Cluster Controller (CC) to process and forward the data received from the end nodes. This architecture runs the Main controller(MC) at the center embedded with admission control(AC) and policy control(PC) modules as shown in figure-2 processing and handling the control logic for the entire network, distributing the control information to all the CCs at different levels. The task of the CC and LC is just to receive and execute the control information. Consequently, energy utilization at each node in the cluster is significantly minimized. The CC, after receiving the control information, could update the same based on the current status and needs of the cluster and communicate the same to all the LCs in that cluster. All these C clusters are connected together along with a base station wirelessly to form the network. The base station is connected to a gateway allowing the end users to communicate through the Internet.

2.2 Proposed Methodology

The SDN-RRP Protocol supports three types of messages to ease the transmission of control and data information among all the nodes of the network.

1) SDN-RRP Reservation-Request Messages: A SDN-RRP reservation-request message is sent by the main controller to the cluster controller to set the traffic control parameters for the first hop.
2) SDN-RRP Path Messages: An SDN-RRP path message is sent by each cluster controller along the path provided by the routing protocol(s). This message stores the path state in each cluster controller.
3) SDN-RRP-Teardown Messages: SDN-RRP-teardown messages are used to remove the path and reservation state before the cleanup timeout period. These messages can be triggered in a cluster controller and main controller whenever timeout period elapses.

Main Controller Modules Functionalities

Admission control module: This module allows to reserve the resources, if the nodes along the path have necessary

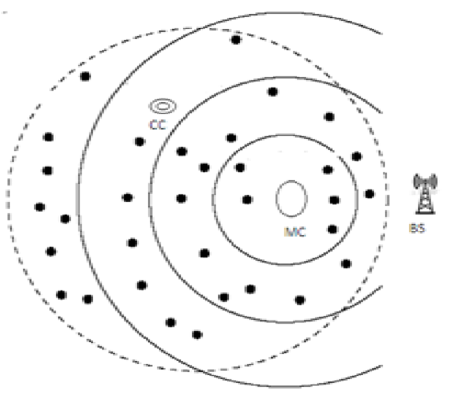

Figure. 1 SDN-Based Clustered Layered Architecture

available resources to achieve the desired QoS using the info-table (soft state), which consists information about the availability of resources at all the clusters. The Soft state refers to a state of intermediate CC that can be kept informed by RRP-WSN messages. The soft state is maintained by the MC to enable the system to change the states without contacting the end nodes each time. To maintain the reservation state, SDN-RRP records a soft state in CCs and LCs. The SDN-RRP soft state is refreshed periodically by SDN-RRP-path and SDN-RRP reservation-request messages. SDN-RRP inspects the soft state time to time to build and forward SDN-RRP path and SDN-RRP-reservation-request messages to the next hops.

Policy control module: This module determines if the priority of the packet sent matches with priority mapping to the resources requested. If both the checks succeed, the MC sends the necessary control information to the CC. Each CC has CC-packet classifier and a CC-packet scheduler as shown in figure-3. The CC-packet classifier classifies the packets based on the QoS class of each packet utilizing the information obtained from the MC. The packet scheduler orders the packet transmission to achieve the desired QoS for each stream. To facilitate this, two queues are considered: Low QoS queue (Q_L) and high QoS queue(Q_H).

The task of the LC is just to receive and execute the commands from the CC. Thus, energy utilization at each node in the cluster is minimized.

The proposed resource reservation protocol SDN-RRP works in three phases: resource discovery phase, handshaking phase, and data transfer phase. In the resource discovery phase, once the sensors are deployed, cluster controllers and the main controller are recognized. All the cluster controllers consign the resource availability information to the main controller to update its info-table. At the end of this I phase, the MC's info-table will have the comprehensive information about the availability of resources at each cluster. The resource discovery phase is executed periodically.In the second phase called handshaking phase, the MC and the CC handshakes with each other regarding information about the different QoS classes and priority to be assigned to the packets. The CC also makes judicious decision about an amount of resources to be allocated for the packet with particular QoS class and priority in the packet classifier based on the type of data. The CC at level -1 also performs the job of assigning priority depending upon the type of data received.

SDN-RRP Session starts- up:

Whenever an event of interest occurs, the sensor node in each cluster senses the data and transmits it to the CC of that cluster at level-1 (CC-L1) by utilizing the resources allocated by MC. The CC-L1 eliminates the redundant information based on the control information received then stores the data in memory and initiate the SDN-RRP path message to the main controller (MC) which is at level-2. After MC receives the path message, the admission control block checks for the availability of resources along the path and policy control block checks for the priority and the amount of resources allocated. If both the checks succeed, appropriate reservation messages specifying the desired resources to be allocated would be sent to the CC. After the CC receives a reservation request message, Packet classifier allocates appropriate resources as per the QoS class of the reservation message received from the MC. Packet scheduler orders the packets for transmission to achieve the required QoS. The forwarding plane transmits the packet towards the base station according to the packet scheduler. The data is transmitted towards the base station using the forwarding plane in a multi-hop fashion traversing intermediate CC so that the critical data reaches the base station with minimal delay and guaranteed QoS. The base station, in turn, transmits the data packets towards the gateway router to forward them towards the destination over the internet. Thus, the protocol significantly reduces the processing liability at each sensor node, which would have required a great amount of energy and time otherwise. Energy consumption and processing time at each node in the cluster is reduced, thereby minimizing the overall energy consumption and transmission delay in the system and hence considerably increasing the overall system performance. The data is transmitted utilizing the resources allocated for the data flow which in turn aids in reliable data transmission with minimal delay.

2.3 *Resource Reservation Protocol for wireless sensor network using SDN Approach (SDN-RRP) Algorithm:*

In the proposed strategy, the network considered is heterogeneous with a set of location-aware LCs and CCs having similar characteristics and are static in nature. The energy model considered uses free space and multipath fading models. The following assumptions are made for the system under consideration.

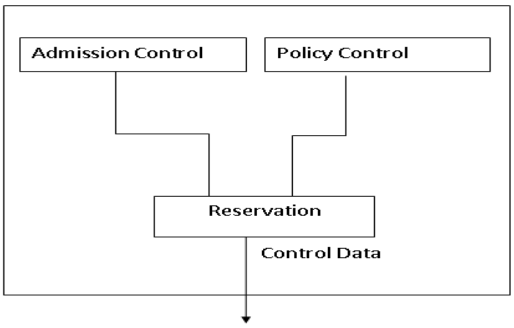

Figure. 2 Admission and policy control modules at Main Controller

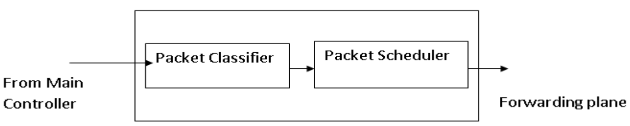

Figure. 3 Packet classifier and Packet Scheduler at Policy Control module.

1. All nodes communicate packets to cluster controllers independently.
2. The omni-directional antenna is used in each node.
3. Bi-directional wireless links are considered.
4. The transceiver has the same receiving and transmission range.
5. Arrival rate of data packets to cluster controller is according to Poisson process with the mean arrival rate of λ.
6. Mean Service time with which Packets are transmitted from cluster controller to Base station is μ.

Every node in the network calculates the energy being utilized for communication with all other nodes. To transmit packets each with b number of bits to the destined node which is at a distance d, the transmitting(E_{TX}) and receiving(E_{RX}) energy consumed by radio are given by

$$E_{Tx} = b\,(\Phi_1+\Phi_2 * d_i^{\gamma})$$

$$E_{RX}= b*\beta$$

Where Φ_1 is Energy consumption factor for being transmitted from the sensor node at a distance d to CC-li, Φ_2 is Energy consumption factor of the amplifier, γ is Path loss component and β is Energy consumption per bit of the receiving circuit.

The total energy required for transmitting, receiving and processing of data at a node is given by

$$E = \left(E_{TX} + E_{RX} + Eproc\right)$$

Where E_{proc} represents Energy required for processing the received data.

The total energy consumption at the network with L levels, C clusters and S LCs with

each cluster is the total energy consumed for transmitting, receiving and processing data at each LC and CC also at MC is given by

$$E^{total} = \sum_{j=1}^{C} E^{CCj} + \sum_{j=1}^{C}\sum_{i=1}^{S} E^{LCi} + E^{MC}$$

Where E^{LCi} is the energy consumed at i[th] LC and E^{CCj} is the energy cosumed for processing at j[th] CC

Data from each LC is tagged with the flag values based on whether it is real time or non-real time data indicating it's criticality, accordingly priority(1 to 5=High, 6 to10=Low) is assigned at CCs of lower layers.

The proposed networking environment can be considered as the M/M/1 queuing model. The packets at each CC-Li are divided among p priority queues. There are Q_K queues where K can range from 1 to P.

Q_1 has the highest priority . . . Q_P has the lowest priority.

The stability condition of the queue is given by

$\rho_1 + \rho_2 + ... + \rho_P < 1$ where ,ρ is the stabilization factor.

The proposed approach assumes two priority classes i.e. P=2.

Then, K can be either H or L based on whether the priority of the data is in the range {1,2,3,4,5} or {6,7,8,9,10}

The packet would be placed

at Q_H if it's priority is in the range {1,2,3,4,5} or at Q_L if it's priority is in the range{6,7,8,9,10}

$$\rho_H + \rho_L < 1$$

Service rate for the packets from Q_H is given by

$$\mu_p^{CC\text{-}Li} = \frac{1}{T_x^{CC\text{-}Li}}$$

Where, $\mu_p^{CC\text{-}Li}$ is the rate of service for the Packets with priority 1 to 5 at the CC-L_i,

$T_x^{CC\text{-}Li}$ Time Taken to forward the x^{th} packet from CC-L_i to CC-L_{i+1}

Delay occurred for transmitting packets of p priorities(L and H) from CC-L_i to CC-L_{i+1} is

$$D_p^{CC\text{-}Li} = \frac{\frac{1}{\mu_p^{CC\text{-}Li}}}{1-\rho_p^{CC\text{-}Li}},$$

The bandwidth required for transmitting packets of p priorities between CC-L_i and CC-L_{i+1} is given by

$$BW_p^{CC\text{-}Li} = \frac{1-\rho_p^{CC\text{-}Li}}{\frac{1}{\mu_p^{CC\text{-}Li}}}$$

Total Delay for p priority packets at Base station (TD_p^{BS}) is given

$$TD_{SDN-RRP}^{BS} = \sum_{p=L}^{H} \sum_{i=1}^{L} D_p^{CC\text{-}Li}$$

Total Bandwidth required for transmitting p priority packets till base station is

$$TBW_{SDN\text{-}RRP}^{BS} = \sum_{p=L}^{H} \sum_{i=1}^{L} BW_p^{CC\text{-}Li}$$

Thus, our Optimization problem is to
Maximize performance of the system
with the constrained that
$TD_{SDN\text{-}RRF}^{BS}$ and E^{total} should be minimum

Algorithms:

Admission control block at MC located at level2

$R_{max}^{CC\text{-}Li}$: Maximum resources available at each CC at level i
$R_{req}^{CC\text{-}Li}$: Resource required for data at CC-Li
Pkt_L / Pkt_H: Low priority packets/ High priority packets
Input: Resources available, Resources required.
Output: Allocate resources and transmit the control message.

```
Begin
While(event occurs)
 Resource allocation for all the packets(z) of the data flow
 For(f=1 to z)
  for(i=1 to L)        //Fn all flow requests
    for(j= CC-Li to CC-Li+1)
      for (n=1 to num)   //num is length of info-table)
        if( P== H)
          if(R_max^CC-Li > R_req^CC-Li)
             R_req^f is allocated
             R_max^CC-Li = R_max^CC-Li - R_alloc^f
          else if(Pkt_L exists)
             Reallocation of resources from Pkt_L to Pkt_H
             R_req^f is allocated
          else
             Place it Q_H

        if(R_max^CC-Li > R_req^CC-Li)
             R_req^f is allocated
             R_max^CC-Li = R_max^CC-Li - R_alloc^f
        else
             Place it Q_L
      End for
    End for
  End for
  //send control messages to all the CC-Li
  For(i=1 to C)
    Ctl_CC-Li =ctl_MC
  End For
End while
End
```

Data forwarding Phase:

Input:s sensor nodes in the cluster.
Output: Sensed data is forwarded.

```
While(1)
  For(j= 1 to L)   // for each level
    For (z=1 to c)      // for each cluster

For(i=1 to s)      // At each sensor node
    if ( event hits )
      Sensed data transmitted to CC-Lz
    for (e=1 to packet size)
     For (g=1 to Mem^CC-L1) //redundancy check
       If (Mem^CC-L1[g]==data[e])
         then
           discard
         else
           Mem^CC-L1[g]=data[e]//memory
allocated.
       endif
      Transmit packets from CC-Lj to CC-L j+1
      utilizing the resources allocated from MC
     end for
    end for
   end for
  end for
 end for
end while
end
```

At CC's of all the levels

Based on the control messages regarding criticality (1-5=High priority, 6-10=Low Priority) of the data arrived from MC, data would be classified.

Input: criticality of data.
Output: data classification, energy consumed values.
Begin:
K=0; l=0 // indexes for Q_H and Q_L
For (i=2 to L)
// Data from CC in all levels is stored in the Q_H and Q_L depending upon the criticality.
for(j=1 to C)
for(k1=1 to S) //check ctl table
for(u=1 to ctln)//ctln is no of entries in ctl table containing control info.
if($p(data^{k1}_{CC\text{-}Li\text{-}1})$ == High) then
$Q_H^{CC\text{-}LI}$[k]= $data^{k1}_{CC\text{-}Li\text{-}1}$ //data of high criticality
$BW\text{-}H^{CC\text{-}Li+1}_{CC\text{-}Li} = BW_H^{CC-Li}$ //BWfor high criticality data
$TD_H^{CH\text{-}Li} = D_H^{CC\text{-}Li}$
$Ec_{Tx}^{CC\text{-}Li} = b_{qHi}^{CC\text{-}Li}(\varnothing_1 + \varnothing_2 * d_i^{CCLi\,\gamma})$
$Ec_{Rx}^{CC\text{-}Li} = b_{qHi}^{CC-Li} * \beta$
$TEC_{qH}^{CC\text{-}Li} = Ec_{Ti}^{CC\text{-}Li} + Ec_{Ri}^{CC\text{-}Li}$
$E_{rem}^{CC\text{-}Li} = E_{initial} - (Ec_{Tx}^{CC\text{-}Li} + Ec_{Rx}^{CCH\text{-}Li} + E_{proc}$
else
$Q_L^{CC\text{-}LI}$[k]= $data^{k1}_{CC\text{-}Li\text{-}1}$ //data of Low criticality.
$BW\text{-}L^{CC\text{-}Li+1}_{CC\text{-}Li} = BW_L^{CC\text{-}Li}$ //BWfor Low criticality data
$TD_L^{CH\text{-}Li} = D_L^{CC\text{-}Li}$ //calculate the delay required.
$b_{qLi} = b_{qLi} + Reb_{qLi}$ //no of bits transmitted will include

retransmission bits
$Ec_{Tx}^{CC\text{-}Li} = b_{qLi}^{CC\text{-}Li}(\varnothing_1 + \varnothing_2 * d_i^{CCLi\,\gamma})$
$Ec_{Rx}^{CC\text{-}Li} = b_{qLi}^{CC\text{-}Li} * \beta$
$TEC_{qL}^{CC\text{-}Li} = E_{rem}^{CC\text{-}Li} - (Ec_{Tx}^{CC\text{-}Li} + Ec_{Rx}^{CC\text{-}Li})$
l++;
k++;
Endif
End for
End for
//packet scheduler orders in the required order and forwards the data in the path predefined by MC
For (i= 1 to p packets)
//transmit packets from CC_{Li} to CC_{Li+1}
Mem $^{CC\_Li+1}$= Mem$^{CC\text{-}L1}$[g]
End for
End

III. RESULTS AND DISCUSSION

The parameters that are taken into consideration for simulating the proposed approach are mentioned in table 1. The architecture designed for simulation consists of a single base station and 6 clusters over an area of 1000*1000 m. Each cluster has 80-100 sensor nodes deployed randomly with a distance to the base station is assumed to be up to three hops (number of levels is 3).

Simulations have been carried out for 6 to 8 runs each with 2000 seconds. The proposed SDN-RRP protocol aims at minimizing the amount of energy consumption at each node by keeping the complete control logic processing at the main controller. This scheme also reserves the necessary resources along the path from the sensor node to Base station according to the criticality of the data packets. Thus, by keeping the complete logic at MC and making CCs and LCs to simply follow and execute the instructions, the amount of energy consumption at both CC and LC is significantly minimized by 20.2% when compared to traditional resource management approaches that does not involve SDN logic [13,14,16 and[20]] as shown in figure 4.

As the time required for processing and routing the data packets at each intermediate CCs is also greatly reduced, the total delay incurred for transmitting the data packets from LC to the Base station is significantly reduced by 5.5% shown in figure.6 ensuring the reduced delay and hence contributing towards the overall improvement of the system performance with SDN-RRP approach in comparison with traditional approaches without SDN concept.

The average of results of several simulations was accumulated and depicted in figure 5. The results infer that energy consumption is minimized nearly by 21%. The proposed protocol reduces the energy consumptions as the control plane is centralized at the main controller which has reduced the burden of each sensor node and cluster controller.

Figure 7 shows the total bandwidth allotted for transmission of high priority data packets from LC to the Base station in a multi-hop fashion is more ensuring the desired quality service for critical data. The graphs depicts that bandwidth allotted for transmission of data packets in SDN-RRP is high by 4.8% thereby guaranteeing the reliable and timely delivery of critical data.

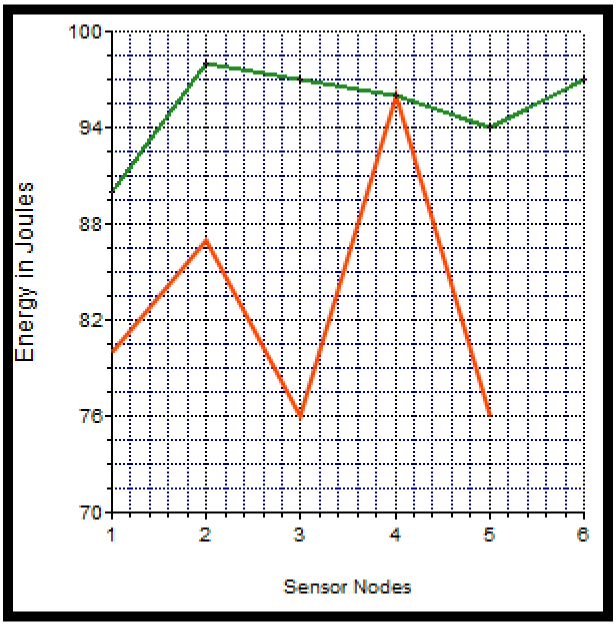

Figure 4 Energy consumed at each node

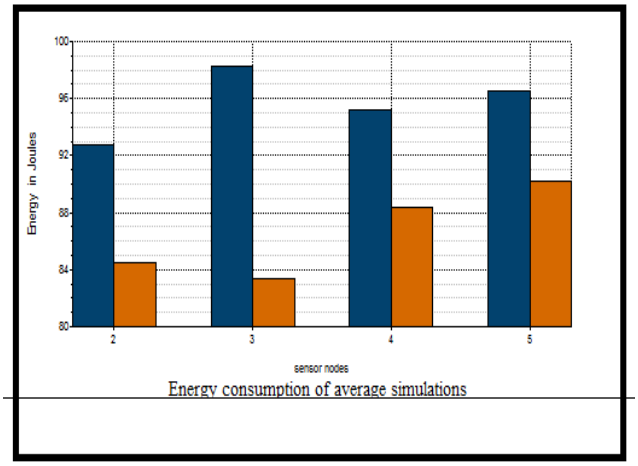

Figure 5 Energy Consumed at each node

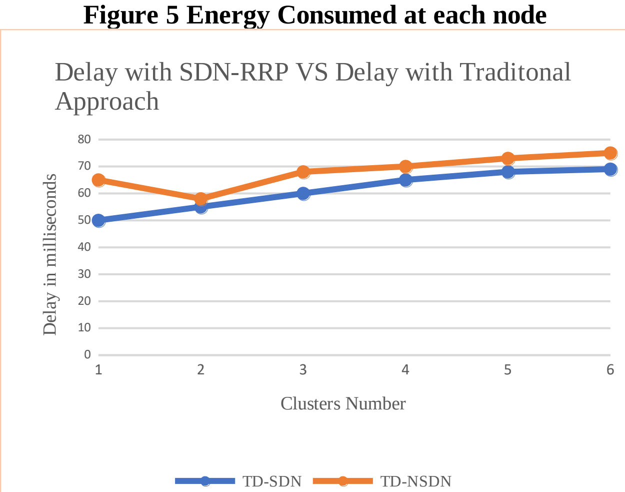

Figure 6. Delay with SDN-RRP VS Delay with Traditional Approach

$$\left(E_{TX} + E_{RX} + Eproc\right)$$

Figure 7. Bandwidth with SDN-RRP VS Bandwidth with Traditional Approach

IV. CONCLUSION

The resource-constrained nature of wireless sensor networks has led to design the protocol for achieving efficient resource reservation with alleviated energy consumption and end to end delay by optimal utilization of resources based on type of data sensed from the physical world. In this paper, we have proposed and implemented an effective resource reservation protocol integrating software-defined networking approach. This technique aids in improving the overall system performance by separating and keeping the control logic processing at the main controller and making CCs and LCs to simply follow and execute the instructions making CCs and LCs frivolous in their functionality. Performance of the proposed algorithms has been evaluated through simulations, and results demonstrate that resource reservation for critical data has leveraged minimization of energy consumption at each sensor nodes. The amount of energy consumption at both CC and LC has significantly minimized by 20.2%. Also end to end delay is reduced by 5.5% in transmitting data packets when compared to traditional resource reservation protocol. Hence the proposed protocol reduces the energy consumption and minimal delay and thereby increase the system performance.

For future research, the work can be extended to tackle the failures in the Main controller and explore various techniques to provide a solution to the failures occurring in the main controller.

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