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Optimal Resource Reservation Strategy for Constrained Networks using SDN Approach for IOT Applications

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Abstract : The resource constraint nature of wireless sensor networks had led to design of mechanisms that results in optimal utilization of resources for varied data traffic sensed from the physical environment. These data may have different QoS requirements depending on the applications like (*i*) Reliable delivery but not tough on timely delivery. (*ii*) Require data delivery timely but not necessarily reliable. (*iii*) Require for both reliable and timely delivery. Thus there is a need for design and development of resource reservation strategy with the capability to support the contrary performance requirements of divergent data types. This paper proposes an optimal resource reservation strategy based on Software Defined Networks for optimal utilization of resources by reserving abundant resources for critical data. Results of the proposed work has proven the increased reliability with minimal delay and hence increased system performance.

Keywords : Constrained Networks, Resource reservation, Software Defined networks, critical data, Internet of Things

1. INTRODUCTION

In recent times the tremendous growth in electronics filed has led to the exponential development in the area of wireless sensor networks [1]. Wireless Sensor Networks (WSN) is one of the key inputs for Internet of Things [3]. WSN includes a base station and outsized number of autonomous devices called sensor nodes containing sensors to monitor the physical world. Each sensor node senses data and communicates the information to the base station in a multi hop manner. The base station in turn communicates to the outside world through the internet. The data received can be used for appropriate action. Each sensor node is a battery operated device consisting limited processing and computing resources. WSN has varied number of applications in all the fields of human life. WSN can be used in human life saving situations. For human life saving situations the data sensed from the sensor node has to reach the base station reliably and in time. The constrained nature of sensor networks poses challenges for reliable and timely delivery of data. There is a need of resources reservation strategy which aids for reliable and timely delivery of critical data for appropriate action to be taken. WSN are battery operated and have limited resources and its energy is very inadequate. It is highly necessary to utilize the energy very ideally, so that it is able to sense critical data and transmit the sensed data to the base station reliably and as quickly as possible. Energy can be sustained by designing mechanism which reduces wastage of energy. Normally energy is consumed and is wasted when the node in the network is in idle listening state and retransmission is more in the network and also for transmitting control packets. WSN poses challenges in end to end communications with minimal delay and

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increasing the network life time by utilizing energy efficiently. Hence there is a need to develop and design energy efficient optimal resource management and reservation protocol which takes in to account the constrained nature of WSN. Software Defined Networks (SDN) can be a promising way of reserving resources along the path from the sensor node to the base station [11]. In traditional Sensor networks all nodes possess the functionalities of sensors and networking which leads to lot of problems [12, 13]. SDN is a new way of viewing how networks are configured, controlled and operated. The networks are controlled by software applications and SDN controllers. It is primarily about policy based automation and facilitates virtualization. Open flow is the standard communications interface defined between the control and forwarding layers of an SDN architecture [11].In this paper a resource management and reservation protocol strategy is proposed based on SDN concepts for optimal utilization of resources by reserving abundant resources for critical data which increases the reliability with minimal delay and hence increases system performance. The remainder of this paper is organized as follows. Section II highlights the related work. Section III describes the proposed work. Section IV provides results and discussions. And section V concludes the paper.

2. RELATED WORK

In this section, related work on resource management in wireless sensor networks is reviewed. In [4] authors have proposed light weight flexible and adaptive resources management architecture. In this architecture, contextual information gathered from the network and service level architecture is used to manage the wireless sensor network resources. Cho, Jiho Kim has proposed resource management protocol. In this work WSN uses the resources of gateway or the server to increase the performance. [5] 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 co relation is being used [6]. In [7] authors have proposed a resource management scheme in bottom up approach. In this scheme sensor node is responsible for job selection using reinforcement learning. Stream authentication and unequal error protection is optimized by allocating resources to reduce image distortion and energy consumption [8]. Wireless sensor devices are managed by using IPV6 on low power wireless personal area network and constrained application protocol [9]. In [10] authors have considered fuzzy logic for buffer allocation and packet dropping for multimedia wireless networks .Buffers are allocated using dropping factor which calculated using fuzzy factors priority, rate of flow and packet size. But none of these papers have considered the concept of reservation of resources using SDN approach. This paper proposes an optimal resource reservation strategy using SDN approach to increase reliability with reduced delay and thus increasing the system performance.

3. PROPOSED RESOURCE RESERVATION STRATEGY FOR CONSTRAINED NETWORKS USING SDN APPROACH

3.1. System Architecture

The architecture of constrained networks considered for this work is a layered clustered SDN based architecture as shown in figure-1. The proposed architecture consists of L layers containing C clusters of s sensor nodes connected to form a network. This network consists of a router which acts as a gateway for connecting through internet. Each sensor node consists of local controller and each cluster has a cluster controller at layer-1. The functionality of the local controller is to receive and execute commands which it receives from the cluster controller. The cluster controller communicates to the local controller the control information using open flow. The resources-memory and bandwidth of transmission links between cluster controllers in the intermediate layers have to be shared among the data received from the lower layers. The sensor node senses the data, if an event occurs and transmits it to the cluster controller at layer-1(CC-L1). The proposed resource reservation strategy works in two phases. In the first phase, once the sensors are deployed cluster controllers and central controller are identified. All the cluster controllers send the resources information to the central controller which is placed at the layer-2. Hence central controller has information about the resources available at the cluster controllers. This phase is called *resource discovery*. The resource discovery phase takes place periodically. In the second phase resource can be allocated in two steps. In the first step which happens at the lower layer (layer-1) the data is separated from the control information and forwarded to the next layer cluster controller, which is designated as central controller (CC-L2) using open flow protocol. Here the controller allocates resources on FCFS basis since cluster controller (CC-L2) may receive redundant data from its descendants at the lower levels, through the data plane. In the second phase as data travels towards the base station, cluster controller(CC-L3) at layer 3 may receive different types of data from lower layers through data planes. This varied data should be prioritized based on criticality which is decided depending upon the content of the data.

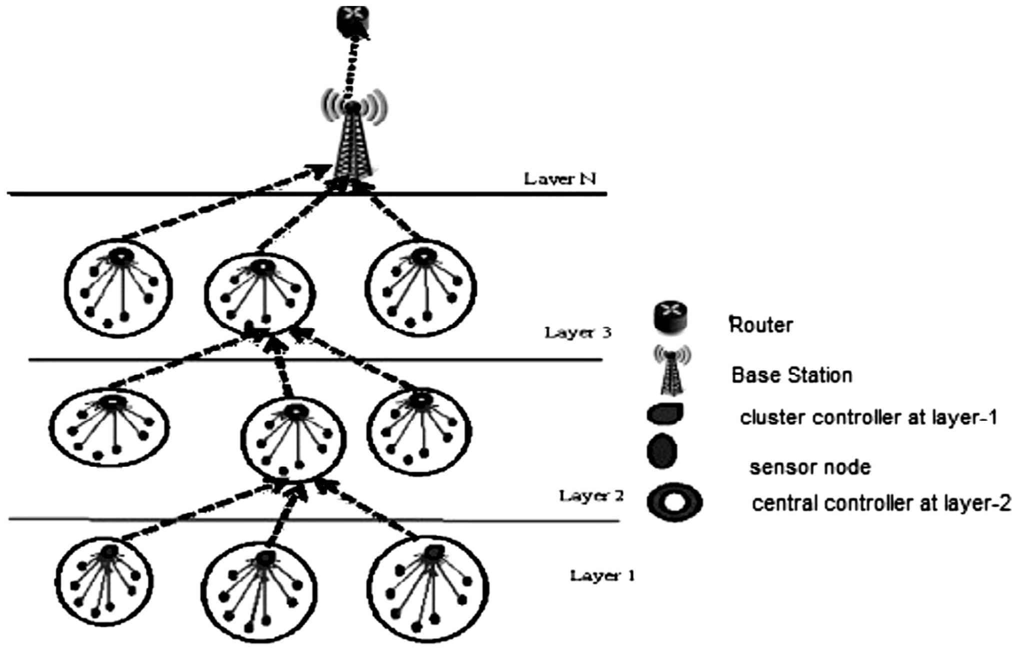

Fig. 1. Layered Clustered SDN Architecture.

CC-L1 has control logic to check and eliminate redundant information and then it sends messages to data plane to be stored in memory. At this phase CC-L1 also transmits handshaking information among CC-L1 to central controller about the priority consideration for critical information to be transmitted. CC-L2, which is the central controller performs the job of prioritizing the data arrived and sending messages about the required resources to the next higher layer cluster controllers. Then data is transmitted towards the base station using the data plane in a multi hop fashion traversing intermediate CC utilizing resources reserved by central controller so that high priority data reaches the next layer CC with minimal delay towards the base station. Thus delay is minimized for prioritized data and there is minimal energy waste with no data loss. There by achieving reliable data transmission. To accomplish this all CC's and Base station are provided with two queues[high = 2, low = 1], the classifies the data according to the information received during handshake. The base station in turn transmits the data packets to IOT router to reach destination over the internet for necessary action.

3.2. Resource Reservation Strategy for Constrained Networks using SDN Approach (RRSCNS) Algorithm:

In the proposed strategy, the following assumptions are made.

1. All sensor nodes have similar characteristics.
2. All cluster controllers are similar in their characteristics.
3. All nodes communicate packets to cluster controllers independently.
4. Omni directional antenna is used in each node.
5. Bi directional wireless links are considered.
6. Transceiver has the same receiving and transmission range.
8. Arrival rate of data packets to cluster controller is assumed to be a Poisson process with mean arrival rate λ_r.

9. Packets are transmitted from cluster controller to Base station with mean service time 1/ μ.
10. There is only one cluster controller in a cluster and one central controller.
11. Buffer capacity of cluster controller and Base Station is limited

Nomenclature used in the algorithm is given in table 1.

Table 1. Nomenclature used in the algorithm

Parameter	***Definition***
R	No of priority queues.
L	No of Layers from sensor node to Base Station
i	Layer No ($i = 2, 3\ldots$)
CC–Li	Cluster controller at layer i
λ_r^{CC-Li}	Mean arrival rate of data packets of r different priorities at CC-Li
ρ_r^{CC-Li}	Utilization of CC-Li for r priority classes
Q_r^{CH-Li}	Low Priority Queue ($r = 1$)High Priority Queue ($r = 2$).
$Q^{CC\text{-}L1}$	Queue at layer1
μ_r^{CC-Li}	Rate at which packet is forwarded in Cluster controller(CC-Li) for packets in $Q_{R,}$
T_i^{CC-Li}	Time Taken by CC-Li to forward the packet
BWR_{CC-Li}^{CC-Li}	Bandwidth between CC-Li and CC-Lj, where $j = i + 1$ for Rpriority Packets
$N_{CC\text{-}Li}$	Number of packets in CC-Li
E_N^{CC-Li}	Mean Number of packets in CC-Li
D_r^{CC-Li}	Delay for transmitting r priority packets from CC – Li
TBW_{CC-Li}^{CC-Li}	Total Bandwidth available between CC-Li and CC – Lj, $j = i + 1$
$TD_R^{BS}BS$	Total Delay occurred at the base station for R priority data
$TBW_R^{BS}BS$	Total Bandwidth reserved for r priority data between sensor node to Base station
Q^{CC}_ size	Queue size at CC-L1

The System model is depicted in Figure-2.

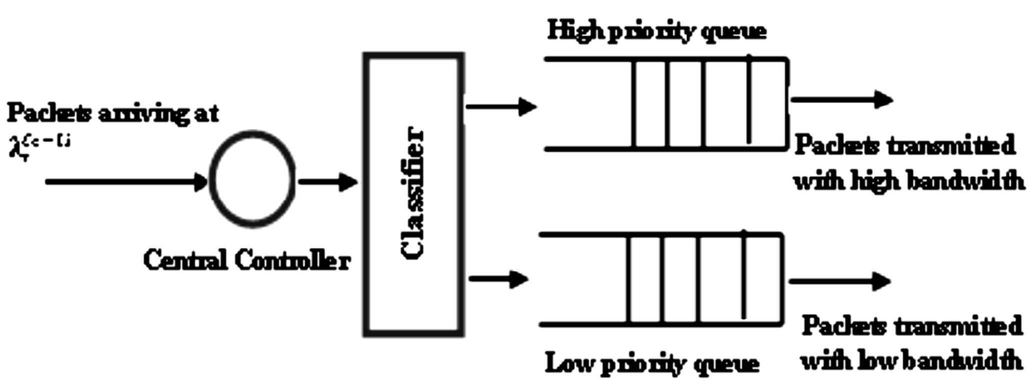

Fig. 2. System model.

Based on M/M/1 queuing model where the packets are divided in to R priority Queues, $r = 1,2,\ldots.R$. Queue 1 has lowest priority and Queue K has highest priority.

The stability condition of the queue is given by

$$\rho_1 + \rho_2 + \ldots. + \rho_R < 1$$

when

$$R = R$$

$$\rho_1 + \rho_2 < 1$$

Service rate for packets in Q_R is given by

$$\mu_R^{CC} = 1 / T_i^{CC}$$

$$\mu_R^{CC} < \mu_R^{CC} \quad (1)$$

$$\rho_r^{CC} = \lambda_r^{CC-Li} / \mu_r^{CC}$$

Mean Number of packets in CC-Li is given by

$$E_N^{CL} = \rho Li / 1 -$$

Delay for transmitting packets from CC-Li is

$$D_r^{CL} = 1/\mu_r^{CC-Li} / 1 - \rho_r^{CL}$$

Hence Bandwidth allocated is

$$BWR_{CC}^{CC} = 1 - \rho_r^{CC-Li} / 1/\mu_r^{CC}$$

Consider

$$R = 2 \text{ priority Classes},$$

$$r = 2$$

Delay for transmitting packets from CC-Li is

$$D_1^{CL} = 1 - \mu_1^{CC-Li} / 1 - \rho_1^{\alpha}$$

Bandwidth allocated between CC-Li AND CC-Lj

$$BW1_{CC}^{CC} = 1 - \rho_1^{CC-Li} / 1/\mu_1^{CC}$$

Total Delay at the Base Station is $$Ti = \sum_{i=1}^{L} D_1^{CC-} \quad (2)$$

Total Bandwidth reserved is $$TBV = \sum_{i=1}^{L} BW1_{CC}^{CC} \quad (3)$$

$$r = 1$$

Delay for transmitting packets from CC-Li is

$$D_2^{CL} = \frac{1/\mu_2^{CL}}{1 - \rho_2^{C}} + D_1^{CL} + D_1^{CL} * \frac{1/\mu_2^{C}}{1 - \rho_2^{CL}}$$

Bandwidth allocated between CC-Li AND CC-Lj

Total Delay at the Base Station is $$Ti = \sum_{i=1}^{L} D^{CL} \quad (4)$$

Total Bandwidth reserved is $$TBV = \sum_{i=1}^{L} BWR_{CC}^{CC} \quad (5)$$

Hence from equation 1 it is deduced that

Our optimization problem is to

- Reduce the delay for critical and important data.
- Maximize the performance of the System by optimally utilizing the resources.

Phase 1: Resource discovery Phase

1. S sensor nodes are deployed for sensing with one base station in a layered cluster architecture.
2. C clusters are formed.
3. Cluster controller at layer 2 is designated as central controller.
4. Central controller periodically sends signals and receives available resources from the remaining cluster controller.

Phase 2: Resource allocation Phase

For (p = 1 to C)

{

for (i = 1 to n)

{

if (event)

{

sensed data transmitted to cluster controller

}

For (j = 1; j < size; j ++) //redundancy check

{

If ($Q^{CC\text{-}L1}[j]$==data)

Then discard //redundant data

}

$Q^{CC\text{-}L1}[j]$ = data//memory is allocated.

}

1. Transmit packets from CC-L1 toCC-L2 using TDMA
2. Transmits criticality of data(R) while handshaking (2 = High priority, 1 = Low Priority)

At Cluster heads of Layer 2 and above until Base station

/*Control information is transmitted through control plane and data plane transmits data according to control plane

Allocated resources. The information exchange between control plane and data plane takes place using open flow*/

For (i = 2 to L)

{

Find the nearest CC-Li+1

If (K ==2)

{

$$BW_{CC-Li}^{CC-Li+1} = BW_{H}^{CC-Li}$$

$$TD_{1}^{CC-Li} = D_{1}^{CC-Li\,(i=1)}$$

}
If (K == 1)
{
$BW_{CC-Li}^{CC-Li+1} 1 - BW_{H}^{CC-Li}$
$TD_{2}^{CC-Li} = D^{CC-L(i-1)}$
}
}

$$TD_{1}^{BS} = \sum_{i=1}^{LN} D^{CC-Li}$$

$$TBW_{1}^{BS} = \sum_{i=1}^{L} BWR_{CC-Li}^{CC-Li}$$

$$TD_{1}^{BS} = \sum_{i=1}^{LN} D^{CC-Li}$$

$$TBW_{1}^{BS} = \sum_{i=1}^{L} BWR_{CH-Li}^{CH-Li}$$

4. IMPLEMENTATION AND RESULTS

In the simulation mode considered in this research work a single Base Station and 6 Clusters are considered. Each cluster has 100 sensor nodes. Over1000*1000m area, placed randomly and their distance to the Base Station is up to three hops. There are two queues High Priority Queue, Q2 and Low Priority Queue, Q1 at CC-Li and Base Station. The table 2 lists the performance parameters considered for the simulation.

Table 2. Performance parameters considered for simulation

Parameter	*Definition*
Area	1000m*1000m
Number of sensor nodes	100
Q_{1}^{CH-Li}	90
Q_{2}^{CH-Li}	40
C	6
Data rate	1Mbps
Packet size	64
Radio Range of sensor	200 m
R	2
Base Station	1
$BW1_{CH-Li}^{CH-Li}$	1.2 – 1.75 Mbps
$BW2_{CH-Li}^{CH-Li}$	0.75-1 Mbps
T_{1}^{CH-Li}	2 mill seconds

The Simulation results as mentioned below are an average of several simulations conducted on the model.The proposed strategy emphasizes towards minimize the delay for critical data by reserving sufficient bandwidth along the path from the sensor node do the Base station using SDN. *i.e.* From sensor node to CC-LI, then from CC-L1 to CC-L2, CC-L2 to CC-L3 so on… until data reaches the Base Station. Here we have taken No of layers to be 3. Figure -3 shows that, the delay for transmitting critical data using the proposed mechanism is less for high priority when compared with delay transmitting the data with low priority.

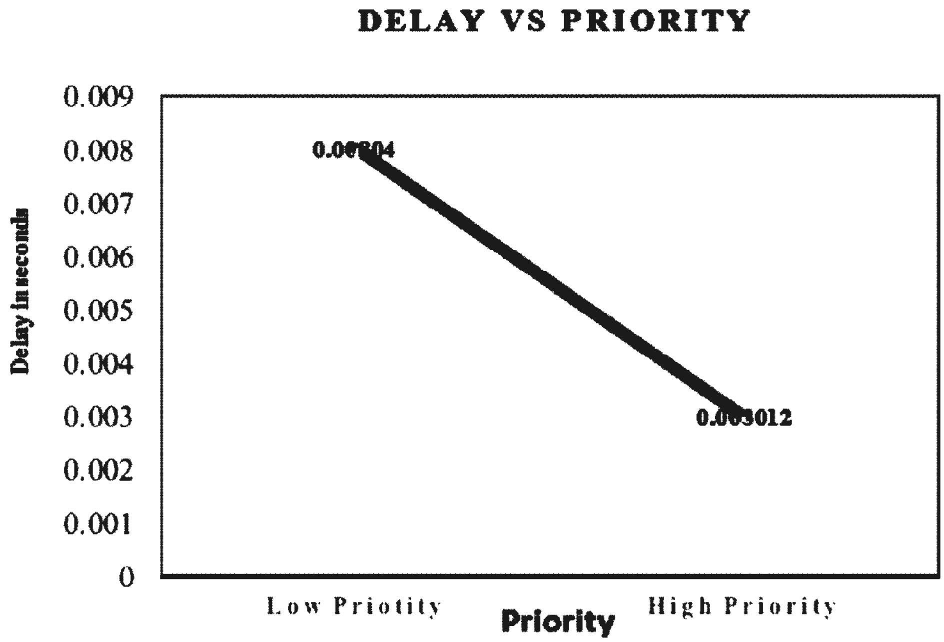

Fig. 3. Delay versus Priority.

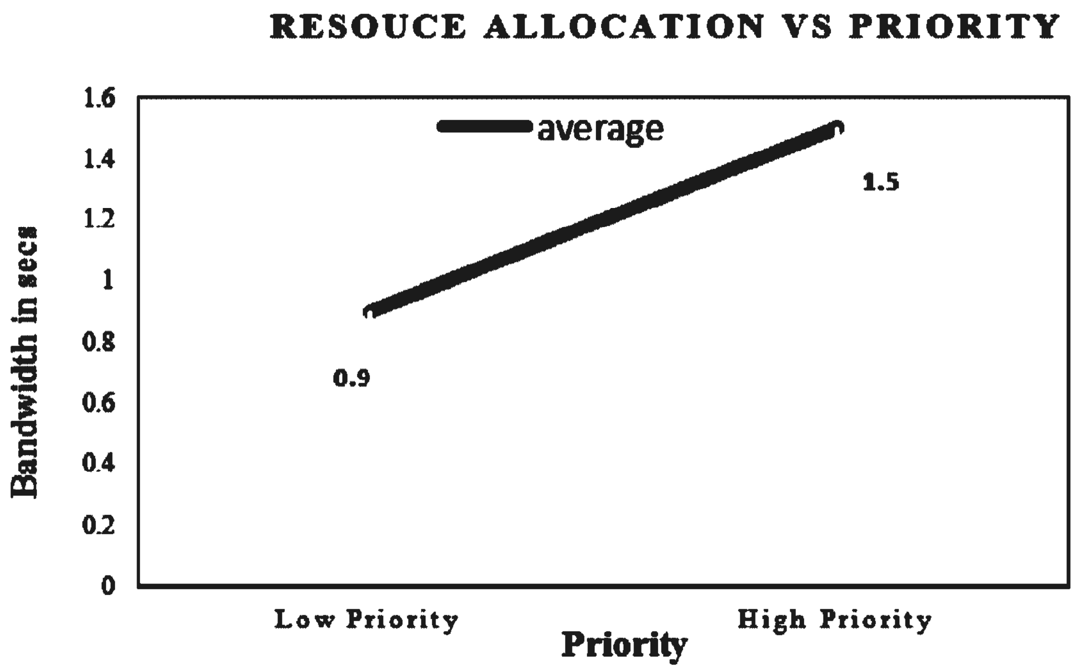

Fig. 4. Resource Allocation Vs Priority.

The resources are optimally utilized with the proposed strategy by allocating sufficient resources to the critical data than normal data and hence achieving the reduced delay for critical data as shown in the Figure-4

4. CONCLUSION

The resource constraint nature of wireless sensor networks had directed to design strategies that results in optimal utilization of resources for varied priority data sensed from the physical environment. Reliability for critical data can be achieved by optimally utilizing the resources. Thus the two phase optimal resource reservation strategy proposed and implemented in this research work has led to removal of redundant data at layer -1 and control logic has been centralized using SDN has resulted in optimal resource reservation for critical data. Thus the proposed strategy has increased the system performance.

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