Optimizing the Performance of Wireless Sensor Network Based on Software Defined Network and Gaussian Filter

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HIGHLIGHTS

- The use of SDN in WSN has become popular due to its outstanding dynamic performance.
- The Gaussian filter is widely used to smooth, blur and remove signal noise.
- QoS in SDN-WSN has proven to be very effective in extending the network's life.
- The process of transmitting and receiving data was organized.

ARTICLE INFO

ABSTRACT

This paper presents software defining network SDN control in wireless sensor networks (WSN) to estimate packet flow, which relies on a Gaussian filter to filter the transmitted signal. The practical aim of this method is to predict the next step of packet flow earlier, which helps reduce congestion if it occurs. The proposed model (SDN-WSN with Gaussian filter) is applied to enhance signal transmission, reduce data error, reduce congestion network and reduce data overflow data. The methodology of the proposed work can be explained as follows: first: distributing nodes randomly; second: Applying the K-mean cluster to choose to select the optimum position of the head cluster node; third: connecting the network using LEACH protocol. Moreover. In this work, SDN with a Gaussian filter is proposed to control the network and minimize data error. It is possible to achieve that by adding buffer memory for each node to store data. The data transmission process is controlled by SDN, and a Gaussian filter is applied before transmitting data to minimize error data. The proposed method's simulation results proved its effectiveness in prolonging the network lifetime by nearly more than 30% rounds than out-of-date WSN, reducing the average density of memory to 20% than out-of-date WSN, and increasing the average capacitance of memory to 20% than out-of-date WSN.

1. Introduction

Recently, it has become commonly popular to use software-defined networks in (WSNs) due to the impressive dynamic performance of WSNs [1,2]. Moreover, several benefits exist when SDN is employed in (WSNs), the following illustrates the benefits: it optimizes resilience, enhances scalability, participates in eliminating network complexity, optimizes management and configuration.

Dynamic reconfiguration of the network is an important feature, especially in a hostile environment, where it may not depend on wireless connections. Therefore, it is preferred to update network routing constantly [3-5]. Although the notion behind the SDN control level is based on a centralized method, it is essential to distribute the SDN controller physically between multimode to achieve fault-tolerance, high performance, and scalability [6,7]. The basic contribution of this paper, this work proposes SDN-WSN having Gaussian filter to assess packet flow volume in the network. Furthermore, the work proposes a queuing model to assess the capacitance of buffer size in SDN with a Gaussian filter to mitigate the effects produced by data noise. Furthermore, this paper proposes an SDN-WSN hybrid with a Gaussian filter to manage and mitigate data noise [8,9]. The methodology of the proposed work can be explained as follows: first: distributing nodes randomly, second: Applying the K-mean cluster to choose the optimum position of a head cluster node, third: connecting network using LEACH protocol.

Moreover, the second section will discuss the related works related to the Gaussian filter and WSN. Section three will present the methodology of the proposed work, section four will discuss the result of the proposed work, in the fifth section will address the conclusion of the proposed work.

2. Related Work and Background

2.1 Related work

Several researchers related to optimizing the performance of WSN have been presented by researchers who majored in the field of WSN. This paper has addressed some of them introduces, as some of the researchers introduced a novel strategy to handle controller placement problem (CPP), which can solve link failure that may occur, latency, and transparency relevant to a wireless South Bound Interface (SBi) [10]. Some researchers introduce the problem related to SDN-CPP as delay and the number of controls forwarding paths between the switches and controllers and each condition related to link failure and formulates that as a multi-criteria optimization problem (MCO). The simulation results show that the proposed algorithm is effective in most cases of link failure; the proposed strategy can guarantee the delay and reliability of the control layer [11].

Some researchers presented Multi-controller Based Software-Defined Networking to minimize the average time when responding to an event of the switches. A genetic algorithm is optimized to solve the relevant problem, Supposing every controller prone to an M/M/1 queuing system[12]. Some researchers propose Garter Snake Optimization Capacitated Controller Placement Problem (GSOCCPP) and moderate breeding states to solve CPP. This succeeded in minimizing the amount of time required by the task to complete its execution compared with the analyzed algorithms [13]. Some researchers proposed (Cuckoo-PC) algorithm, which aims to find the global best solution through the imitation of the brood parasite of Cuckoo birds. To assess the performance of the algorithm it was making a comparison with other methods. It is proven that Network's performance can reduce the average distance between controller sensors and up to 9% and 13%, individually [14].

2.2 Wireless sensor network (WSN) Basics

This paper briefly introduces the main concepts of WSN, including network structure, standards, research challenges, and application cases. Each sensor node in WSN has a sensing region capable of sensing objects and events that are close adequately to be detected. Additionally, each node is interconnecting through a wireless interface with other nodes in that node's communication range [15-18]. Wireless sensor networks (WSN) are used in many applications such as telemedicine, automotive, environmental, domotics, or military [19]. Table 1 illustrates some of the commonly used systems or technologies developed for critical applications.

2.3 Overview Software-defined networking (SDN)

Software-defined networking is a new network structural design that can beat present structural design defects [20]. It works to separate the data plane (DP) and control plane (CP) of the network, meaning that the controller can configure forwarding elements (FEs) by the use of accurate forwarding processes to data packets of dissimilar flows. The controller attains ample information for performing the mission. That is why the control protocols, which are distributed, would not be required among (FEs). Moreover, the controller might be interacting with applications to enhance the network [21, 22]. Table 2 gives these arguments in terms of comparisons.

Table 1: Common WSN applications and their technology systems

Application	Condition	Parameters	Technologies
Agriculture	Planting: Soil preparations	Soil: pH, Nutrients, Humidity, etc.	AgroSense, AgriServe, etc.
	Animals: Moving patterns and behavior.	Position, Animal Tracking, etc.	ZebraNet, WiSense
Military	Surveillance [Safety and Security]	Infrared, Motion, etc.	Ultra-Stable Tripods, Radar, EcoKit, etc.
Health	Operative or intensive Care	Heartbeat, Pulse, Rate, BP, Temperature, etc.	iMONNIT, Vifisense, Autonomous Systems, and Biomechatronics
Infrastructure	Surveillance, Control and Prediction, Measurements, Maintenance	Temperature, Motion, Infrared, Vibration, Strain, Stress, Air-Flow	Camera Systems, SensoNode, VIBCODE Transducer, etc.
Transportation, Automotive	Asset tracking, Presence	Radio Frequency, Accelerometer, etc.	Trackers, RFle, Smart Logistics, etc.
Water Quality	Observation and Control	pH, Iron, Nutrients, Color, etc.	Libelium Smart Water, etc.

Table 2: Comparison between an SDN network and a traditional network

Potential Operate Features	SDN Separation of the control and data forwarding planes. Easily controlled and deployed	Traditional (Nonsfl) Network Hard-structured and logically coupled operations. Very complex control
Implementation	Fast and easily implemented. Adapt to the need of the application environment.	The time involved to implement. Operate in dedicated environments.
Stability	Currently unstable with few technological supports.	Stable with great network support.
Architecture	A software-oriented with customizable resource features. Centralized network intelligence.	Hard-structured and operated on dedicated and proprietary devices.
Configuration	Configuration can be largely done remotely. Software monitoring and operation are done centrally.	Network devices need to be configured directly and individually.
Management	Easily managed using Alp's- Can be easily modified depending on the network demand.	Difficult to manage as network devices are solely proprietary and hard to access
Maintenance	It can be easily maintained as new services, or network upgrades can be done easily without affecting the whole network.	Difficult to maintain as the whole network might be affected by a small change in the network.
Error Checking	Easy to check network errors as software modules are dedicated to doing this. Therefore, errors can be quickly isolated easily from the network.	Error checking is extremely time-consuming and difficult to isolate as operators have to the whole check network even for small errors
Novelty	Network innovation becomes easy as new network features could be attached to the existing infrastructure. It does not need to revisit the whole network processing.	A simple change will require a serious study and understanding of the whole network structural design. Therefore, innovation is possible but difficult to implement.

2.4 Gaussian filter

Gaussian filter is included in filter with linear type, which uses Gaussian function to determine the weight value of each group. Gaussian filter is commonly utilized to smooth, blur and eliminate noise in the signal. The filter's mechanism is to move the filter mask center from one point to another. In each pixel (x, y), the filter's result at that point is the multiplication sum of the filters' coefficients and the corresponding neighboring filter mask range. In contrast, it is defined as a process to get values depending upon their values, adjacent pixels, and kernel matrices, as represented in equation 1.

$$G(x) = \frac{1}{\sqrt{2\pi\sigma}} \, exp\left(\frac{-x^2}{2\sigma^2}\right)$$ (1)

Where σ represents the distribution's standard deviation when the value of σ is larger n the Gaussian distribution curve is wider and the peak drops [23-27].

3. The Proposed Model: Architecture and Specifications

In this system, controllers have been suggested in the SDN platform. Those controllers are capable of computing the physical area's data flow. The SDN controllers can choose CH and cluster members CMs in the sensing zone. It is proven in the results relevant to service quality. The proposed model can compute theda rate of data flowing and coordinate the buffer capacitance with a set of active sensor nodes in the network to prevent buffer overflow. The proposed system is composed of 3 layers.

- The first layer is composed of dissimilar kinds of WSN devices.
- The second layer is composed of several edge servers deployed in WSN devices and SDN controllers.
- The third layer is the cloud DC, which is supposed to have huge resources.

SDN employs WSN to verify WSN nodes activation in real-time for fulfilling application requirements. It is possible to consider the controller as the SDN control layer's brain, able to manage spike SDN 's data flowing. This work proposes an SDN controller with a Gaussian filter for managing the WSN and enhancing data.

Figure 1 illustrates the queuing model, where the error (t) represents variation between desired buffer size and the actual buffer size. The controller, which is proposed, plays an essential role in the process of approximation to a proper magnitude of the packet flow to the successive round, with SDN offline training for determining the buffer size capacitance. The total waiting time of packets in the queue represents the sum of the back and back delays in the links and the queue delay processed in the cloud. This work uses SDN for choosing the ideal Forwarding Cluster Head FCH OpenFlow to transfer traffic. Nevertheless, it is possible to run IoT & Remote Patient Monitoring platforms depending upon an SDN control. However, its outputs are Boolean values. Therefore, logic 1 can be described as FCH, and logic represents cluster members as illustrated in Algorithm (1) and Figure 2.
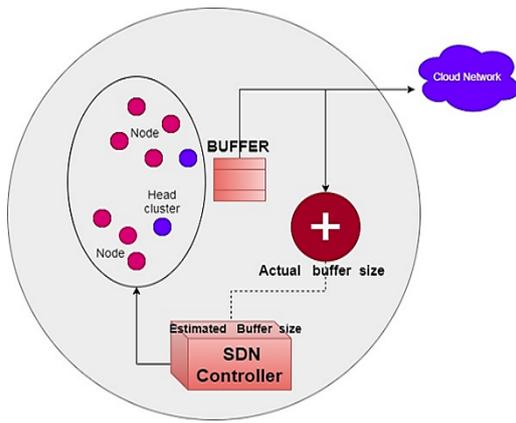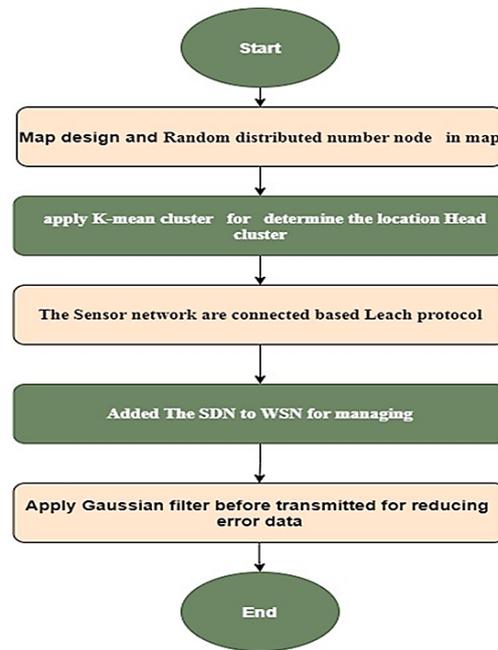
Figure 1: Proposed queuing model

Figure 2: The Block diagram of the proposed work

4. Simulating Results

This paper proposes an intelligent SDN control with a Gaussian filter using MATLAB® R2020a for the simulation. Scenarios are considered with N randomly placed sensors in the sensing area of square shape and with a transmitting range to every sensor unmoved at twenty–five-meter. Moreover, the number of sensors is varied, ranging from (80 to 120) for controlling the network density. Figure 3 shows the process of implementation of the zone. The sensing nodes generate traffic at the start of every scheduling period. In other words, sensor (s) conducts low-flow to high-flow. After that, the flow will be directed to Forwarding Cluster Head. The controller of SDN minimizes the volume of congestion. It is possible to classify Forwarding Cluster Heads as congestion. When this ratio exceeds the level of threshold, where the Buffer size of CH equals 250 packets, the Buffer size of each node equals 50 packets. Initial energy E equals 0.5 J. Random distribution can be carried out by generating randomly selected 100 point graphs (100 × 100) and distributing them on BSs at (50,50), as illustrated in Figure 3. When nodes are distributed, the K-mean cluster is applied to choose the optimum position of FCH, which will get all the nodes (100) to enter into k- mean cluster and cluster it into four groups, where each group belongs to the subset of nodes. The center point represents an HC position. When nodes are distributed, the node and the CH are determined, then the CH is connected with the node, the model is the LEACH protocol as illustrated in Figure 3. This figure shows the effect on the k - mean to determine HC, where there are the 4HCs, are in position (67,19),(20,19),(15,68), (72,75) in order The Intelligent the SDN controller to WSN, When WSN model is prepared. The Intelligent SDN is applied, Simulation was run with the parameters the area is 100×100. There are 100 sensors with 4 HCs, and the CH Buffer size equals (250 packets), Each node's Buffer size equals 50 packets, and initial energy E equals 0.5 J.

More importantly, there are five assumptions implemented to the network, as follows:

- The whole immobile sensing nodes create a stationary flow per unit of time.
- Two activities exist in sensing. The 1st activity creates traffic flow, and the 2nd activity is forwarding the traffic Forwarding Cluster Head.
- Connecting between Forwarding Cluster Head, cloud, member nodes encompass single-hop wireless links having OpenFlow software-defined network switch.
- Sensing nodes can authenticate their mode based upon density and CH buffering capacity
- Flow quantity that sensing nodes transmit has to be proportionate with the capacity of the network channel.

This work applies the Gaussian filter with SDN to organize the data transmitting and receiving among nodes and CH, or CH and router to minimize the overflowing and memory usage, prolong the timelife of sensors in network raise the WSN effectiveness as explained in Figure 4.

Figure 4 shows that conducted two scenarios can be conducted. The first one: applying a Gaussian filter in a Wireless sensor network. The second one is applying WSN using a Gaussian filter. It was observed that the Gaussian filter reduces the data error by roughly 5% compared with the out-of-date method. Then, comparing WSN without using SDN, WSN with SDN from memory capacity, memory density, and node energy, as illustrated in Figure 5. From Figure 5 above, we noticed that QoS of SDN-WSN network proved its effectiveness regarding prolonging the network lifetime nearly more than 30% rounds than out-of-date WSN,

reducing the average density of memory to 20% than out-of-date WSN, and increasing the average capacitance of memory to 20% than out-of-date WSN. Table 3 summarizes the benefits of SD-WSN over traditional WSN technologies. Firstly, in a traditional WSN, the sensor nodes can have many different structures, including normal nodes, routers, and coordinators for node function types. Additionally, the node application types are the same as the function types. On the contrary, in SD-WSN, there is only a small difference between the node structures.
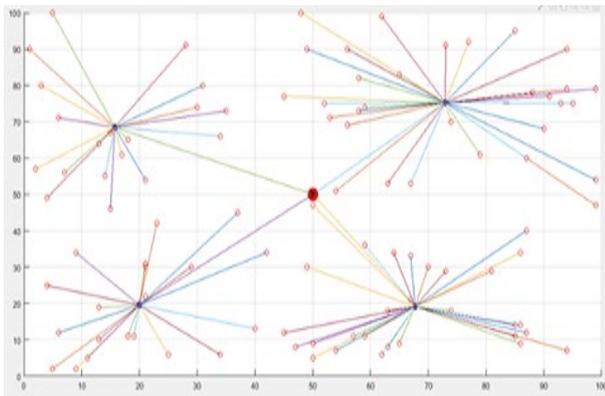

Figure 3: Show the connection of node and CH based on Leach protocol
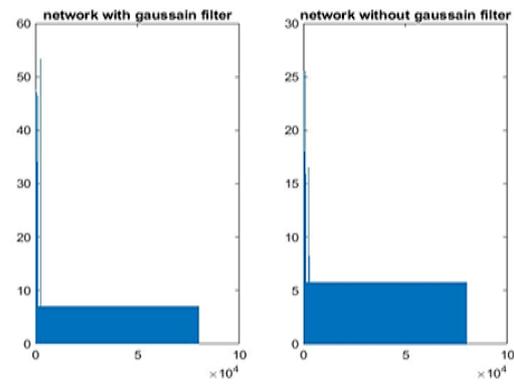

Figure 4: The compute the data error in the dissimilar scenario (a) the scenario Gaussian filter in WSN (b) the scenario without Gaussian filter in WSN
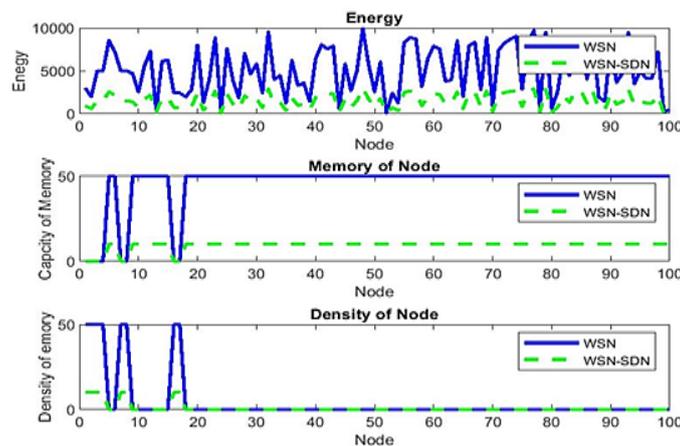

Figure 5: The QoS the SDN-WSN and WSN form Energy, Memory of node, density

Table 3: Pros and cons of current WSN technologies and SDN-WSN

Traditional WSN	SDN-WSN
Con: broadcasting messages periodically	Pro: service response and more flexible
Con: the variety of node structures	Pro: difference of node structures is quite small, and network structure is smaller
Con: data transfer from all directions	Pro: finding the path according to the direction of nodes and more adaptive for the IoT
Pro: Do not need a controller	Con: Need a controller

5. Conclusion

The paper proposed the SDN-WSN model that offers controllers in the SDN queue to estimate the sensor zone of the packet flow. Moreover, one of the controllers is working proactively in a Gaussian filter with SDN to assess sensor packet flow. Simulation results showed that the QoS was optimized in a Gaussian filter with SDN-WSN. The Kmean cluster was proficiently capable of choosing the cluster head and its members in the sensing zone, as illustrated in the results related to Quality of service. This model can estimate the packet flowing rate. That will contribute to coordinating the buffer capacitance available with a set of active sensing nodes in the network to stop buffer overrunning. We noticed that the QoS of the SDN-WSN network proved

its effectiveness in prolonging the network lifetime by about 30% rounds than out-of-date WSN, reducing the average density of memory to 20% than out-of-date WSN, and increasing the average capacitance of memory to 20% than out-of-date WSN.

Author contribution

All authors contributed equally to this work.

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Data availability statement

The data that support the findings of this study are available on request from the corresponding author.

Conflicts of interest

The authors declare that there is no conflict of interest.

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