Dynamic Load balancing in SDN using Energy Aware Routing and Optimization Algorithm

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***Abstract*—In software defined networking, load balancing is a crucial management operation for moving traffic packets from source to destination. Ant Colony Optimization (ACO) was employed with dynamic load balancing to enhance SDN performance in existing works. In order to improve the search for the ideal path, response time, span-time, and energy consumption, it is proposed in this article to employ energy-aware routing with a Genetic Algorithm (GA) and ACO load balancing. The goals are to minimize energy consumption while maintaining a quality of service for user flows and to achieve link load balancing. Simulation results demonstrate that the proposed scheme performs better in terms of response time and energy consumption.**

***Index Terms*—Software Defined Networking, Load Balancing in SDN, Genetic algorithm, Ant Colony Optimization**

I. Introduction

Internet protocol networking world needs an upgrade to effectively handle the massive increase in network traffic caused by the rapid global expansion of the Internet of Things (IoT). To effectively address this problem, Software Defined Networking (SDN) was developed. SDN modifies and replaces traditional network management by vertically partitioning with network components, separate implementing network controller logic inside the routers and switches, and centralizing network control. It also introduces to programming the network logic. The most common method of communication between the switch plane and control plane in SDN is the OpenFlow protocol [1].

SDN solutions are designed to enhance network control and management. The architecture is divided separately into three layers: applications, control, and infrastructure, which communicate through APIs. The application layer is where your organization's application lives. This can include anything from intrusion detection and threat detection systems to firewalls and load balancers. Unlike traditional networks, that require specialized apps to manage data plane behavior, SDNs use controllers. The control layer is the SDN's brain. It runs on its own server and manages network policies as well as data traffic flow. It communicates with the system's APIs both northbound and southbound in the SDN structure. The physical aspect of the network is represented by the infrastructure layer. It is made up of switches that route incoming and outgoing network traffic to their respective destinations. SDN technology streamlines and simplifies how businesses manage data flow within their internal networks. There are many advantages of SDN. It reduces the complexity of operations and does not require manual configuration. Simple third party integration, open APIs for quicker time to market, improved network management and visibility reduce the hardware footprint and cost [2]. SDN was also used by CloudSeeds to build a highly robust infrastructure. CloudSeeds' approach has eliminated traditional Layer 2 issues such as broadcast storms and switching loops, allowing it to maximize operational efficiency and customer satisfaction by utilizing its available capacity. In this article, LB is powered by an SDN that combines energy-aware routing with GA and ACO, called Energy Genetic Ant Colony Optimization (E-GAACO). The current ACO algorithm based approach makes use of a positive feedback mechanism to update the flows path information as they are transmitted. However, this might lead to a local optimal solution and erroneous path selection. Although the local optimal solution can be avoided using the random selection policy, even a suboptimal solution is not guaranteed. These problems hinder ACO's ability to choose the best SDN path. ACO still has problems with the trade-off between random selection and the local optimal solution. Therefore, GA is used in conjunction with ACO to reduce crashes and improve LB for SDN. In this work, the energy optimization model is also employed with some constraints to illustrate the energy sensitive routing problem. A two-stage approach has been proposed to solve the modeled energy-aware routing problem. The first stage, the periodic offline phase, builds the optimal energy subgraph from the original network tree. The second stage, the event-driven online phase, finds an appropriate route for each incoming data stream based on the size of the incoming data stream and QoS requirements to achieve the best possible load balancing of the result. network connection. The ant's behavior became the basis for the ACO algorithm. All ants roam aimlessly at first, but eventually return to the nest after leaving the pheromones in search of food. That way, instead of wandering aimlessly, other ants can follow the trail of the pheromone. This method was used to identify and correct computer network problems and is the best network path. Several ACO-based schemes, such as Ant-Net, Ant-HocNet, and Hop-Net, are used to address the routing problem of computer network paths [3,4]. Genetic algorithms are based on the selection and development of genetic

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steps. It is widely used to generate high-quality solutions for searching and optimizing problems using biologically-inspired operators such as mutation, crossover, and selection. To solve this problem, the algorithm must follow the following five stages. Initial population, fitness function, selection activity, crossover activity, and mutation activity [5].

To effectively locate the pathways of the flows for load balancing, another second stage GA is applied for search to properly minimize the search space path. The proposed approach significantly outperforms round-robin (RR) and ACO algorithms in terms of the round-trip time (RTT) and packet delivery rate [6]. Among the various protocols provided for SDN, the always used OpenFlow protocol to implement SDN. In OpenFlow the programmability is the main features. The required network functionality can be easily achieved by programming the controller. The total SDN structure consists of three layers [7]. The application layer is situated above the control plane, while the infrastructure layer lies below. Figure 1 illustrates the OpenFlow protocol based on the architecture of SDN.

II. Related Work

To enhance the performance of SDN in terms of load balancing and power efficiency, several studies have been reported in the literature. The studies that solved the issue addressed in this work are reviewed here. The work presented in [8] presented Energy Aware Fruit Fly Optimization Algorithm to distribute load among virtual machines in a cloud system. Energy Conscious EFOA-LB is the latest algorithm swarm intelligence inspired by the Drosophila of the foraging behavior that reduces energy consumption while achieving a balanced load on virtual machines. In order to uncover problems that could be regarded inefficient load balancing and performance enhancement, a study proposed by Riyaz et al. intends to analyse various artificial intelligence and conventional load balancing strategies in SDN [9]. Yang et al. addressed the issue of deploying load balancing controllers to lower average controller load and other performance indicators including propagation delay and network stability while meeting delay and throughput constraints [10]. The G-ACO scheme by Xue et. al combines GA operations with the ACO algorithm to speed up searching path and ability to improve to find the ideal paths in the searching [11]. In a scheme proposed by Li et. al., a dynamic transport network uses the breadth first search (BFS) algorithm to reassign switches to different subdomains. Extensive testing shows that this scheme outperforms propagation of affinity and algorithms of genetic in terms of stability, accuracy, and load balancing in multicontroller deployments [11]. Torkzadeh et al. presented [12] large scale simulations in scenarios with different between traffic patterns and thresholds. The routing scheme show that the results that significantly reduces net- work power consumption, especially in congested traffic with mouse-like flows. Its meeting the user's QoS requirements can provide effective link load balancing. To ensure fast processing times and optimal use of cloud resources. In [13], ACO, combined with a multi-controller pro classification, Here, the job classification distinguishes between central and subordinate managers. The basic ACO algorithm gives good results, but requires a lot of computation to work perfectly.

III. Proposed work

Packet loss rate and delay time are the two criteria used to evaluate the Quality of Service (QoS) of the network. The G- ACO algorithm is suggested because the ACO algorithm used in SDN for LB has limitations. It carries out the GA's crossover, mutation, and selection processes. The goal is to speed up the convergence to the ideal load balancing and the ability to identify the global optimum. The packet loss rate and sending delay time will then both be reduced. It is commonly known that GA performs admirably for broad worldwide searches. Nevertheless, feedback data cannot be used, and there are numerous iterations that are redundant. Finding the answer effectively is likewise extremely rare. ACO has a positive feedback mechanism in contrast. The second level's limited pheromone availability, however, results in a rather slow rate of searching. The G-ACO algorithm benefits from both the GA and ACO's advantages. Initial population, Fitness function, Selection, Crossover, and Mutation were the stages that were individually defined [3]. Reducing the number of physical computers that house network components like switches and servers is one of the key methods used in SDN to reduce power usage. Virtual machines are used to generate network components (VM). The physical machines can contribute significantly to energy savings by the results of optimal placement and correct the packaging of virtual network elements. The Migration of VM mostly used and techniques in this regard [14]. Software based solutions offered in this area are created using routing and scheduling techniques to save energy [15]. These systems are called Green Scheduling and Energy Aware Routing (EAR). The two primary EAR methods are Adaptive Link Rate and Sleep Mode (ALR). Finding and putting to sleep the network path with the fewest active switches is the goal of sleep mode. On the other hand, ALR technology seeks to spread the load over the network [8]. However, sleep mode becomes ineffective when ingress traffic swells during typical peak hours or when packet loss rate or latency increases. Therefore, a hybrid solution using both sleep mode and ALR is useful for day and night traffic. In order to define the problems discussed in this research, the behavioural logic of the controller is split into two stages: online and offline. To increase a performance parameter, the controller has more modules installed. Other modules were also modified and used in accordance with the method's specifications. Let's take a closer look at the controller part. Relationship between offline and online phases of control logic. As shown in Figure 2 of the Energy-GAACO flowchart, the connections between these two phases are added to GAACO for different results and modified graphs. During the online phase, incoming data streams are routed and connection loads are balanced according to requirements using the Event-Driven Online Phase Modified Weighted Dijkstra algorithm. There

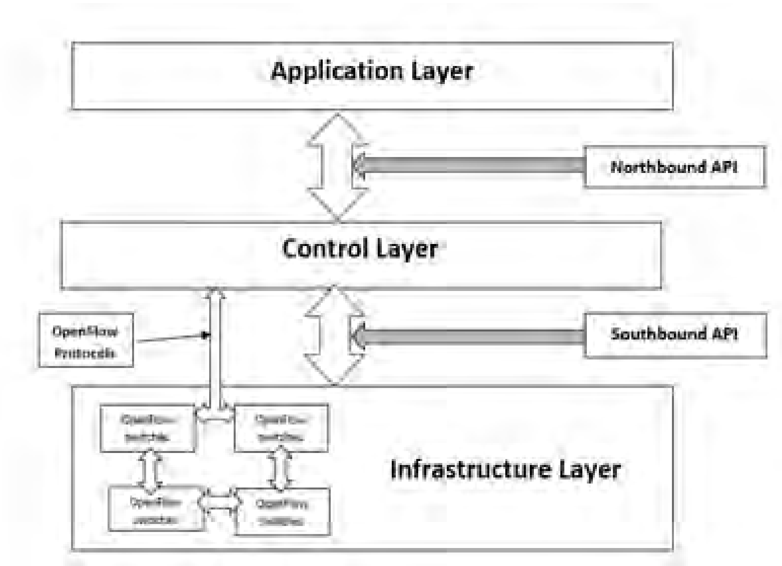


Fig. 1. SDN based on OpenFlow protocol

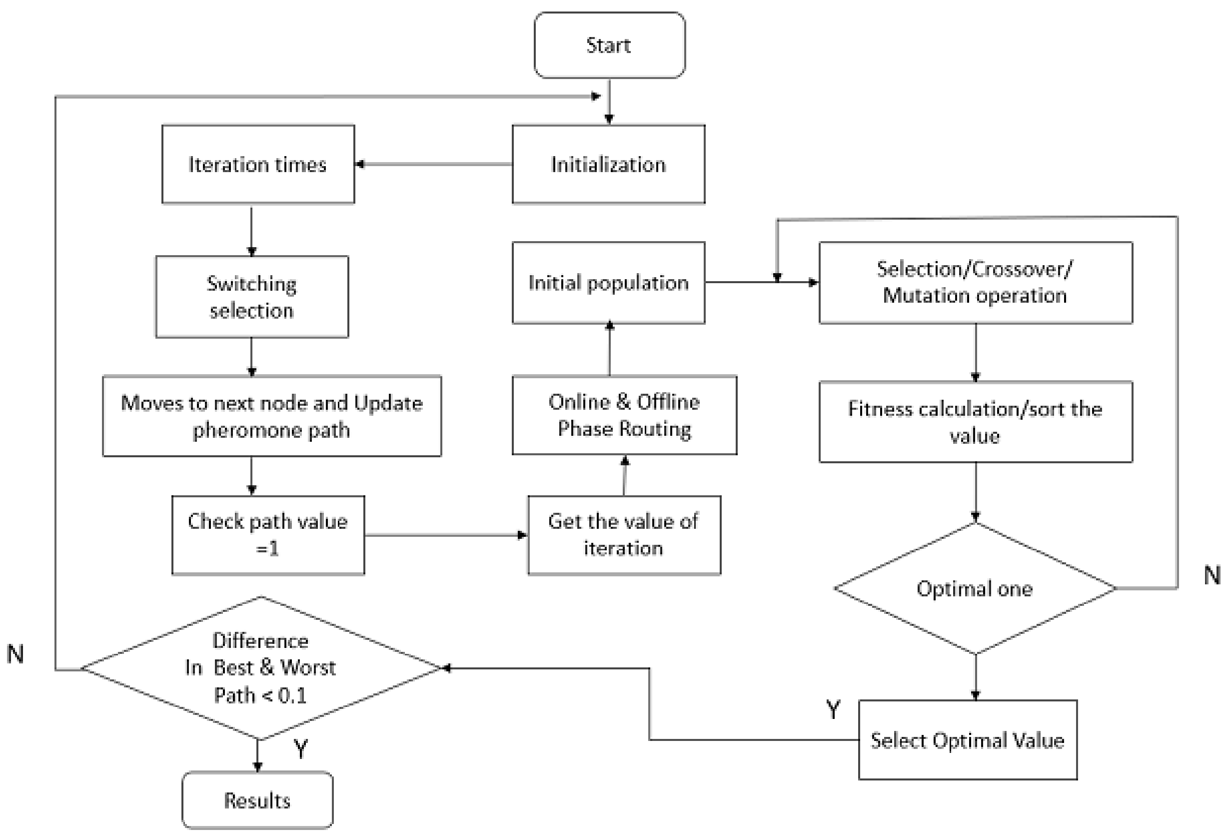


Fig. 2. The flowchart of the proposed Energy-GAACO

are two critical inputs for this method. Weights and network architecture. This algorithm's input topology is the updated network created during the offline phase. This routing method can support a range of applications that need a certain amount of bandwidth or can stand certain delays. Link utilization is often used as a weight in this technique to distribute the load among several pathways. This algorithm's primary goals are to balance the load on connections and fulfil the QoS requirements of incoming flows for a certain service [torkez]. Phases of periodic offline section outlines the processes taken to create the updated graph, which serves as the problem's new energy-optimized topology. The major goal of changing the original chart is to create a new graphic that would optimise the total amount of network power used. Keep in mind that the offline algorithm functions passively. To put it another way, all rules are executed during the online phase; no rules are specified in the flow table. The duration of the offline phase algorithm's periodic execution is set by the pattern and velocity of incoming traffic as well as the length of the simulation run. Separate tools are used for SDN controllers and switches due to the separation of control and data planes. Controllers and switches consist of OpenDayLight or Mininet. However, it integrates energy-aware routing algorithms into GAACO's SDN dynamic load balancing to improve system parameters. Previously, dynamic load balancing in GAACO was simulated in the Mininet simulation. In In this study, the performance characteristics Packet Delivery Ratio, Packet loss, Average Delay, Energy consumption, Response Time, Make span, and Average Throughput are improved using the NS3 modelling tool and energy-conscious routing capabilities. In Figure 2, the suggested work framework is shown. In this study, the performance characteristics Packet Delivery Ratio, Packet loss, Average Delay, Energy consumption,Response Time, make span, and Average Throughput are improved using the NS3 modelling tool and energy-conscious routing capabilities. In Figure 2, the suggested work framework is shown.

Let's take a closer look at the controller part. Relationship between offline and online phases of control logic. As shown in Figure 2 of the Energy-GAACO flowchart, the connections between these two phases are added to GAACO for different results and modified graphs.

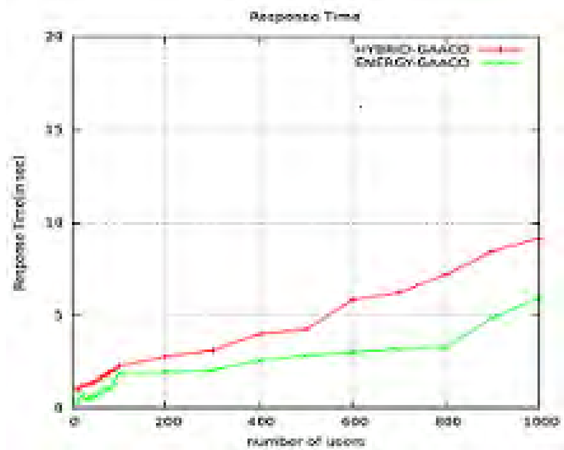
The Event-Driven Online Phase modified weighted Dijkstra algorithm is used in the online phase to route incoming data streams and balance connection loads based on requirements. This algorithm has two important parameters. Weights and network topology. The modified graph produced during the offline phase is used as the input topology for this algorithm. This routing algorithm can accommodate a variety of services that require specific bandwidth or tolerate specific delays. This algorithm typically uses link utilization as weights to spread the load across different paths. The main purpose of this algorithm is to perform load balancing on connections as well as to satisfy the QoS requirements of incoming flows according to a particular service.

The Periodic offline phases this part contains the steps to arrive at the modified graph as the new energy-optimized topology of the problem. The main purpose of modifying the original chart is to get a new chart to optimize the overall network power consumption. Note that the offline algorithm works passively. In other words, no rules are established in the flow table, instead all rules are implemented in the online phase. The offline phase algorithm runs periodically, the duration of which is determined based on the pattern and speed of incoming traffic and the duration of the simulation run. Separate tools are used for SDN controllers and switches due to the separation of control and data planes. Controllers and switches consist of OpenDayLight or Mininet. However, it integrates energy-aware routing algorithms into GAACO's SDN dynamic load balancing to improve system parameters. Previously, dynamic load balancing in GAACO was simulated in the Mininet simulation. In this work, the NS3 simulation tool is employed and energy-conscious routing features are used to improve the performance parameters such as Packet Delivery Ratio, Packet loss, Average Delay, Energy consumption, Response Time, Make span, and Average Throughput. The proposed work framework is depicted in Figure 2.

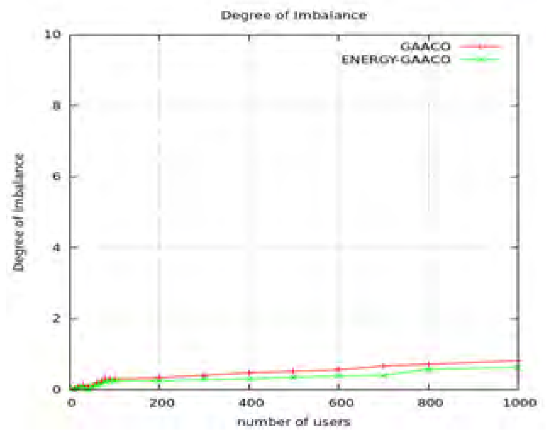
IV. Experimental Results

Simulation are performed using NS3 platform. There are separate tools used for the SDN controller and transformation when the control plane and data plane are separated and run in Mininet tools in the previous simulation [16]. In this article, the OpenFlow and NS3 controller libraries are used to configure the controller and switch respectively. First, a brief presentation of these tools is given. NS3, a discrete event network simulator for the Internet is employed on this work to obtain experimental results. NS3 helps to create different virtual nodes (i.e. real-life computers) and with the help of different Helper classes it allows us to install devices, internet stacks, applications, etc. at our buttons. NS3 supports learning, prototyping, testing, debugging, and many more tasks that will benefit from a full desktop test network [17].

From the simulation results, it was observed that the response time shows better results compared to the hybrid GAACO method. Figure 3 a shows the response timeline by number of users. The proposed scheme Energy-GAACO algorithm for latency and packet loss rate are very efficient in LB for the almost the same regards to the destination. Figure 3 b shows the E-GAACO approach. This greatly reduces the degree of imbalance, makes the order performance more effective than other algorithms, and makes the parameters easier to identify. Figure 3 c shows the consumption in joules against the number of controllers. Energy consumption as a key performance indicator for all systems. Energy-conscious E-GAACO aims not only to achieve efficient processing and use of system resources, but also to minimize energy consumption. In Figure 4 a, the E-GAACO approach is evaluated using response time, Makespan, and energy consumption as performance metrics between switching systems. Also, in terms of the number of users, the value rate is lower than hybrid GAACO. Also, another part of Makespan with load shown in Figure 4 b explains how load affects the system



(a)



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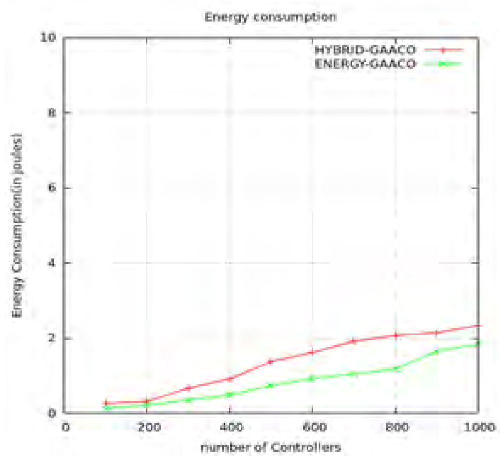
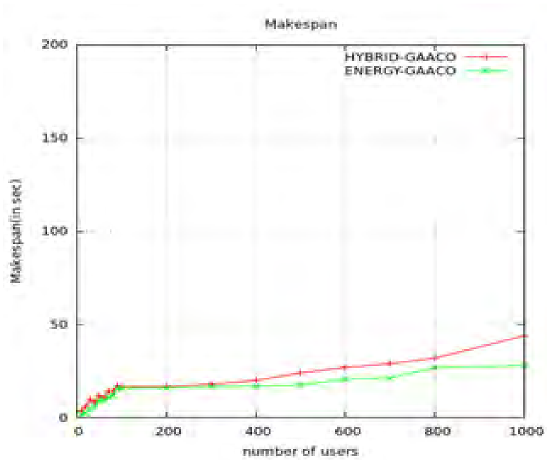
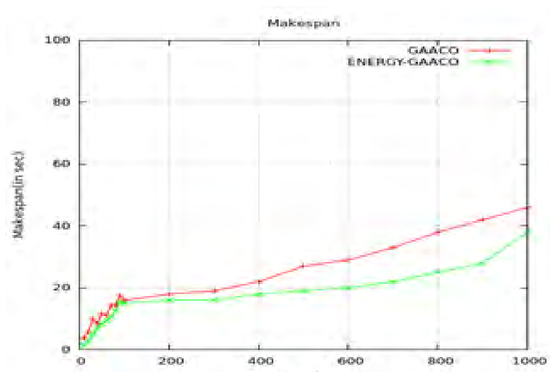


(c)

Fig. 3. a. Response time Vs Users b. Degree of Imbalance Vs Users c. Energy Consumption Vs Controller



(a)



(b)

Fig. 4. a. Makespan vs Users b. Makespan with Load vs users

and performance compared to hybrid GAACO. The goal is to simultaneously minimize manufacturing margins and data center costs while designing load balancing solutions.

V. Conclusion

Load balancing is a very important issue for SDN is due to the separation of the control plane and the data plane. The Energy-GAACO scheme execute the initial population, fitness function, selection, crossover and mutation of the steps of algorithm to enhance the speed of path search and the capability of searching for an optimal path in the process with combine execution of a two-phase software defined network-based routing mechanism that aims at minimizing energy consumption while providing a certain level of Quality of Services for the users flows and considers the link load balancing. By implementing the proposed scheme into the load balancing module of OpenFlow controller and dynamic load balancing with GAACO, better results were obtained using energy-aware routing. The simulation results show that the proposed Energy GAACO mapping suggestively improves the Makespan time, transmission time, energy consumption and packet loss rate.

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