Improved Routing Efficiency and Scalability of WSN over Congested Network

S. Mohanarangan
Computer Science and Engineering
Arunai Engineering College
Tiruvannamalai, Tamilnadu, India

D. Sivakumar
Electronics and Communication Engineering
Easwari Engineering College
Chennai, Tamilnadu, India

***Abstract*—Performance and scalability are key factors when considering suitable network architecture for wireless networks. In the context of ad hoc networks, topology changes seamlessly while sometimes functional planning is necessary. The performance and scalability of the wireless network is often reported by disrupting the traffic speech of the wireless sensor network. This issue focuses on packaging and packet loss due to interference caused by atmospheric factors, such as weak signal, memory leakage sensor tip, ring signal, and sudden changes in topology, namely this is considered incorrect as a lock. It is important to distinguish between cluster and interference with a complete metric that helps calculate computing and scalability effectively. Scalability depends solely on the efficiency of the rotation system around the atmosphere due to the cost-effectiveness and dynamic variability in the rotation path between the actual nodes. When traffic and networks suddenly increase and responsibilities increase, the problem becomes more serious. This paper examines the scalability and performance of the network based on the simulation work performed as the parameter shown above**

***Keywords*—Wireless Sensor Networks, Congestion Control, Routing Protocol, Scalability, Beacon Vector Protocol**

I. INTRODUCTION

Sensor networks consist of many small sensor devices that can perform various measurements of their surroundings. These sensors are usually distributed throughout the sensor array to gather information about their surroundings.

Different routing protocols have been designed and implemented for WSN [1]. The design of these routing protocols is influenced by many factors, in which the scalability factor is considered one of the important factors. . Therefore, routing protocols used for wireless sensor networks should support network scalability, where such protocols should work well as the network grows and the workload increases [2].

As the routing packets with an extensive network of wireless sensors occur on nodes with limited resources for storing packets and updating routing table processing, route processing becomes a challenging problem.

To overcome these limitations, therefore, an efficient and scalable design of routing protocols for packet routing in sensor networks is required [2]. Such routing protocols should prevent the performance of wireless sensor networks from decreasing as the network expands.

Evaluating the scalability problem in wireless sensor networks is a real challenge due to the different routing protocols, the large number of nodes and the wide range of applications in sensor networks. Therefore, the evaluation of the scalability of network sensors is not practically possible in a real network and the use of a network simulator will provide a meaningful insight into the study of the scalability of a sensor network [3]. The purpose of this article is therefore to create a detailed simulation framework that accurately models the various network routing protocols

II. IMPROVING THE ROUTINGP ROTOCOLS' SCALABILITY

A. *Routing Protocols for Scalability*

Various routing protocols are designed for data routing in wireless sensor networks. These routing protocols take into account the characteristics of the sensor nodes together with the application and architectural requirements [4]. Three different protocols were selected in this evaluation study: flood protocol (FP) [5], beacon vector routing protocol (BVR) [6] and Probabilistic Geographic Routing Protocol (PGR) [7] (see Figure 1). The use of these three different protocols to evaluate the WSN scalability issue could be extended in future work to support other protocols.

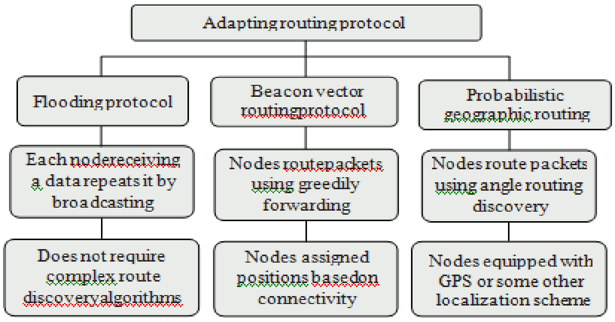

FIGURE1: Routing protocols for scalability evaluation

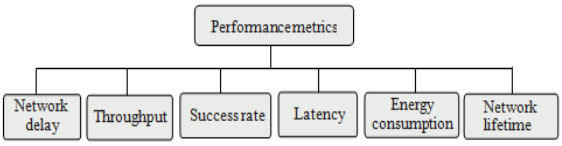

FIGURE2: Metrics for performance Measurement

The Beacon vector routing protocol (BVR) is a hierarchical routing protocol that assigns coordinates to nodes based on a vector of the number of hops over a small set of beacons and defines the distance of those beacons metric. BVR drives selfish packages that go through another leap. That is, closest to the target according to this beacon direction. Probabilistic geographic routing protocol (PGR) is location-based routing that assumes that each node knows its geographical coordinates through some location scheme, such as GPS. The overflow (FP) protocol is one of the available flat routing protocols. In this protocol, each node receiving a packet simply passes it to all its neighbors until it reaches its destination. The Flood protocol was chosen because of the simplicity of this flat protocol, which can be used in comparison with other protocols of this protocol's scalability [4].

III. THE QUNATITATIVE AND METRICS COMPARISON

To compare the scalability of the FP, BVR, and PGR protocols, quantitative metrics were used to measure and evaluate the performance of simulated routing protocols. The frequency of multiple experiments was determined for each metric. A set of performance metrics used for comparison in the selected protocol of the route of his work is shown in Figure 2. Each of these measurement parameters can be briefly described as follows [8].

A. Network Delay

This performance metric is used to measure the average delay between sending data packets. End-to-end delay is the average time spent between the first packet sent by the source and the time required for the destination to successfully receive the message. This delay measurement takes into account queue and packet release delays

B. Network Throughput

The end-to-end network transmission rate measures the number of packets received at the destination per second. This is an external measure of the effectiveness of the protocol.

C. Success Rate

The total number of packets received at the destinations verses the total number of packets sent from the source.

D. Latency

The average message remaining is defined as the average time between the start of data delivery and the arrival of the data to the address of interest in the latency measures time performance for the individual message [9].

E. Energy Consumption

Power consumption is the sum of the power used by all the nodes in the network. The power used by a node is the sum of the power used for communication, including transmit (Pt), receive (Pr), and reduce speed (Pi). Assuming that each transmission consumes one unit of power, the total power consumption is equal to the total number of packets sent over the network.

F. Network Lifetime

It is considered as the time until message loss rate is above a given threshold. The more complete definition for the lifetime of the network is “time to network partition” [10]. Network partition occurs when there is a cut-set in the network. It will be introduced as a new metric, which will use energy variance.

$$\text{Network lifetime} = E - (U + \sigma),\quad \text{where } U = \frac{\Sigma U_i}{N} \qquad (1)$$

E is the total initial energy at each node (full battery charge), U_i is the average used energy, N is the total number of nodes in the network, and σ is expressed as;

$$\sigma^2 = \frac{(U_i - U)^2}{N}. \qquad (2)$$

IV. SENSORSIM - SIMULATOR

Many network simulators are currently available such as SensorSim [12], TOSSIM [13], NS2 [14], OPNET [15]. However, we decided to use the prowler simulator in this research work because of our previous experience with this simulator, easy to use, and it is available online.

We have used the prowler network simulator to evaluate the protocols performance and specifically to measure their scalability. A prowler is an event-driven tool that simulates the nondeterministic nature of the communication channel and the low-level communication protocol of the wireless sensor nodes [4]. To produce replicable results while testing the application, prowler can be set to operate in deterministic mode also. It can incorporate arbitrary number of nodes on arbitrary and even dynamic topology. Prowler models all the important aspects of the communication channel and the application. The tool is implemented in MATLAB, thus it provides a fast and easy way to prototype applications, and has nice visualization capabilities [10].

The non-deterministic nature of radio propagation is characterized by a probabilistic radio channel model. Applications interact through a series of events and commands, just like in real Tiny OS applications. The radio propagation model determines the strength of the radio frequency signal at a given point in space for all transmitters in the system. This information can be used to assess reception conditions in receivers and to identify collisions. Similar to real Tiny OS apps, it is event based. The simulator notifies you of critical application code events such as initialization completion, packet transmission, packet reception, packet collision and clock ticking. The application can then initiate actions such as setting the clock and sending packets. These can trigger other events. Several debugging/visualization tools are also available, such as turning LEDs on and off, drawing lines and arrows, and printing text messages

A. Protocol’s Performance

A set of simulations are used to evaluate the performance of the protocols: FP, BVR, and PGR. The simulations are all performed using prowler under the default radio model $\sigma_\alpha = 45$, $\sigma_\beta = 0.02$, and $p_{\text{error}} = 0.05$. The average radio range of transmission was a radius of 10 m. However, the radio model in prowler was setup to model the transmission range as an imperfect circle. The network setup consisted of 100 nodes dispersed in an area depicting100m×100m.

The simulation is done on the random network model, where node placements are randomly changed to a uniform square area. The sensors are distributed in a regular grid with a random offset.

The performance of the logs is rated under the two parameters that are primarily referred to in terms of simulation time in seconds with difficult quantitative metrics include (conversion rate, latency, and throughput). Second, this is reflected in the relationship between average delays, total throughput, and total energy consumed. All results are from five runs for any network model for each of the three protocols. Figures 3, 4.5 and 6 illustrate this performance of the flooding protocol. Figures7, 8, 9, and10 illustrate the performance of the PGR protocol and Figures 11, 12, 13, and 14 illustrate the performance of the BVR protocol

B. Flooding Protocols and Its Performance

Figures 3–6 are illustrating the flooding protocol performance.

C. Performance of PGR Protocol

Figures 7–10 are illustrating the PGR protocol performance.

D. Performance of BVR Protocol

Figures11–14 are illustrating the BVR protocol performance.

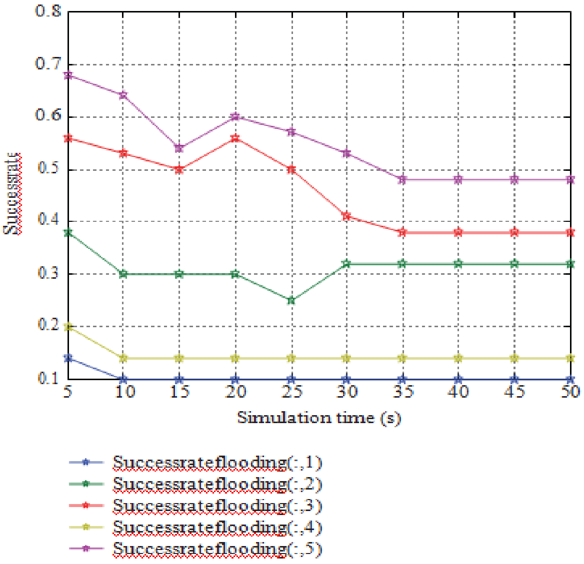

FigURE3: Success rate assessment

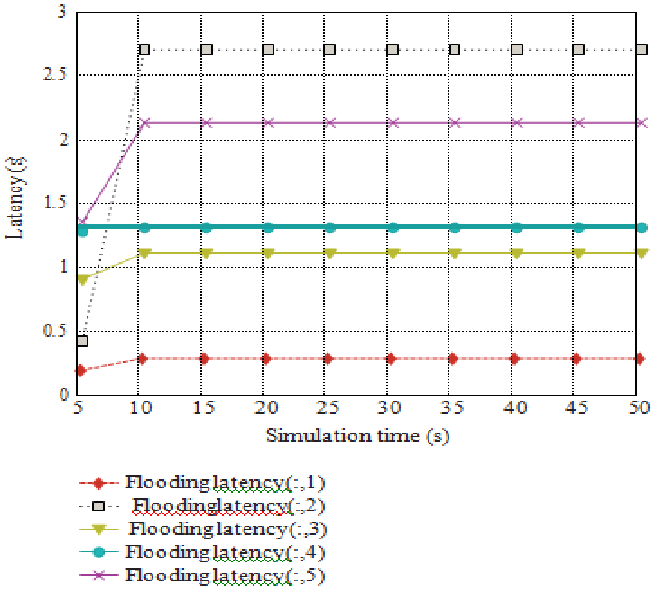

FigURE4: Time and Latency.

E. Influence of routing metrics on scalability according to packet generation frequency

The first study of the network scalability for the selected routing protocols is by using different packet generation rates in a prowler simulator. We randomly place 100 sensornodesina100m×100msensorfieldforeachprotocol.The default prowler radio model is used. Each routing protocol test is performed (with query and event locations randomly selected) which, started by one packet and then increased the number of packets. In this section, performances of the selected routing protocols with increased workload are evaluated as follows;

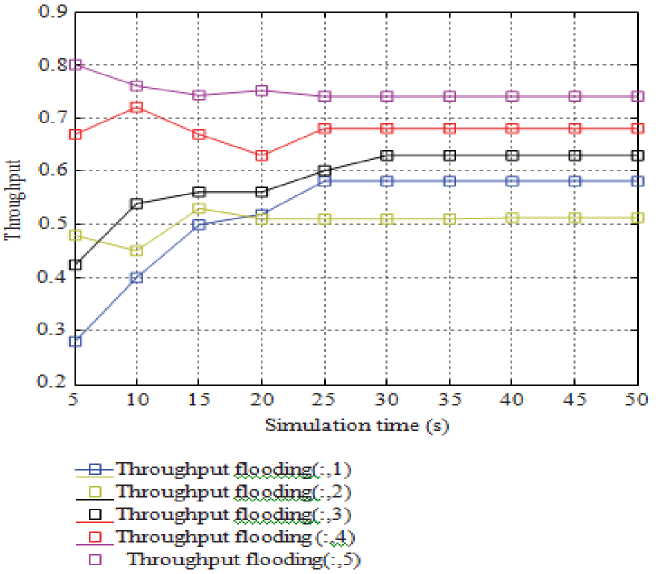

FigURE5: Throughput assessment

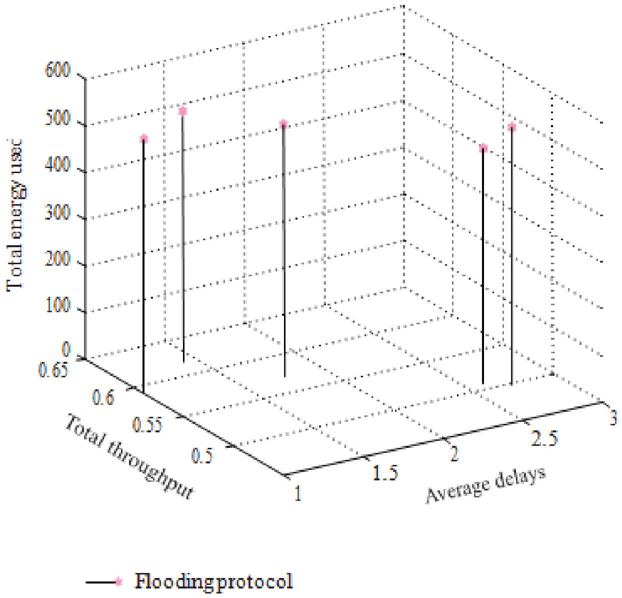

FigURE6: Delays— Throughput— Energy used in total

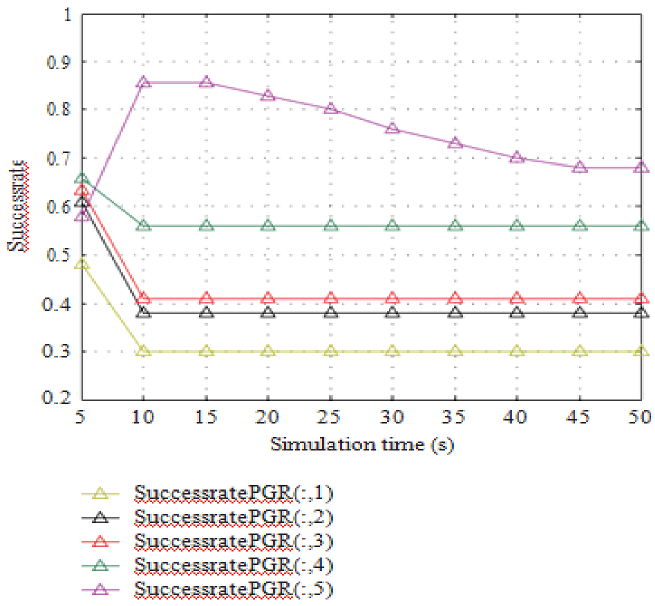

Figure7: Time and success rate assessemnt

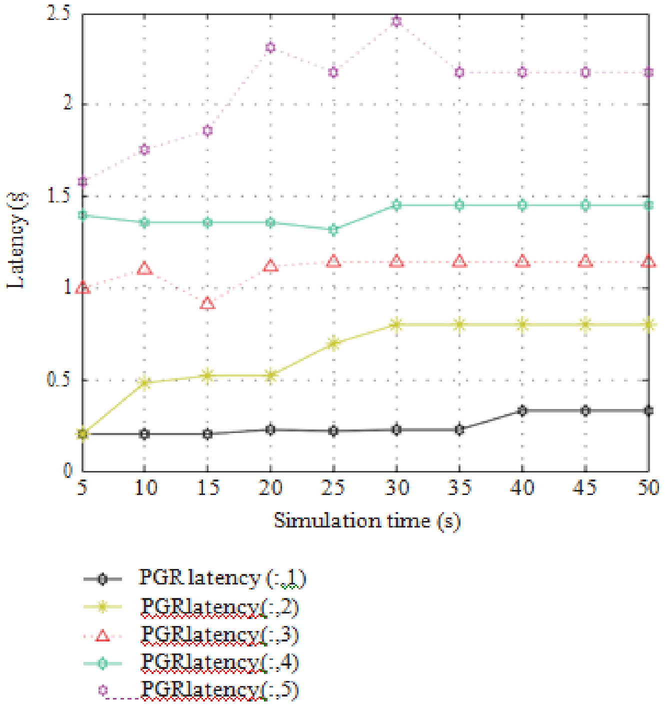

Figure8: Latency Measurement.

Figure 15 compares the energy used for the flooding, BVR, and PGR protocols with respect to packet generation rate. The results show that the energy used experienced by BVR protocol is lower than the other protocols. Message delay can be an important parameter for protocol scalability substantially low relative. The delay feature can be used as an exchange to extend network performance due to protocol constraints. As shown in Figure 16, the BVR protocol reached the minimum latency between the PGR and flood protocols as the packet generation rate increased.

With increasing the packet generation rate, the average packet delay in the flooding protocol gave the highest delay among others as shown in Figure 17. As an average, this highest value was 0.264 second. For the BVR protocol, this was the best because it gave much lower delay than the two other protocols that intern it gave an average of (0.075) second.

Figure 18 shows the network lifetime of the three pro- tocols as the packet generation increases. We observe that the network lifetime of each protocol is decreased. The BVR protocol was the longest network lifetime while the flooding protocol gave the shortest network lifetime. This was expected since flooding is a very energy-consuming task

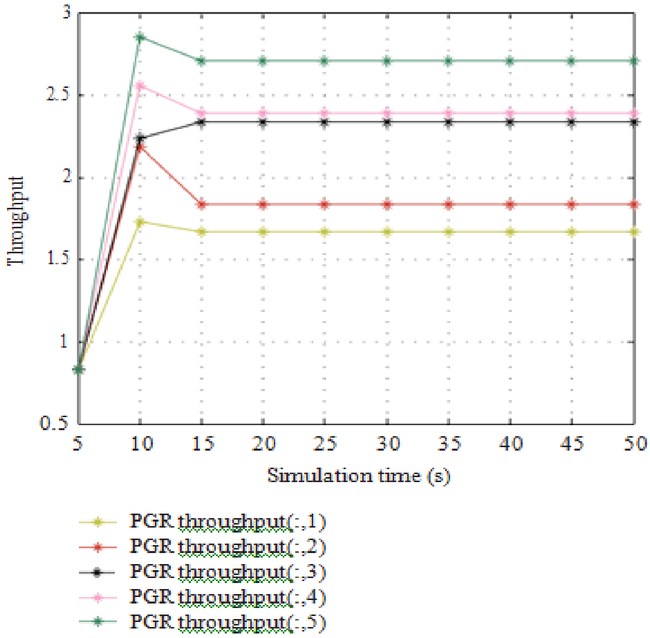

Figure9: Time and Throughput assessment

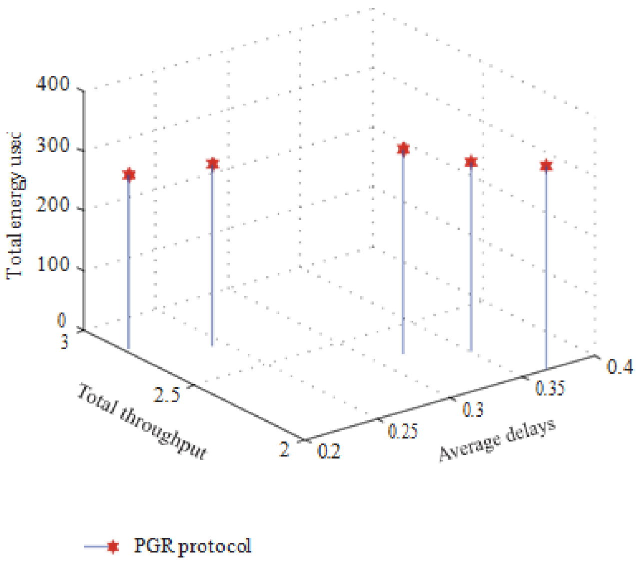

Figure10: Delays— Throughput— Energy used.

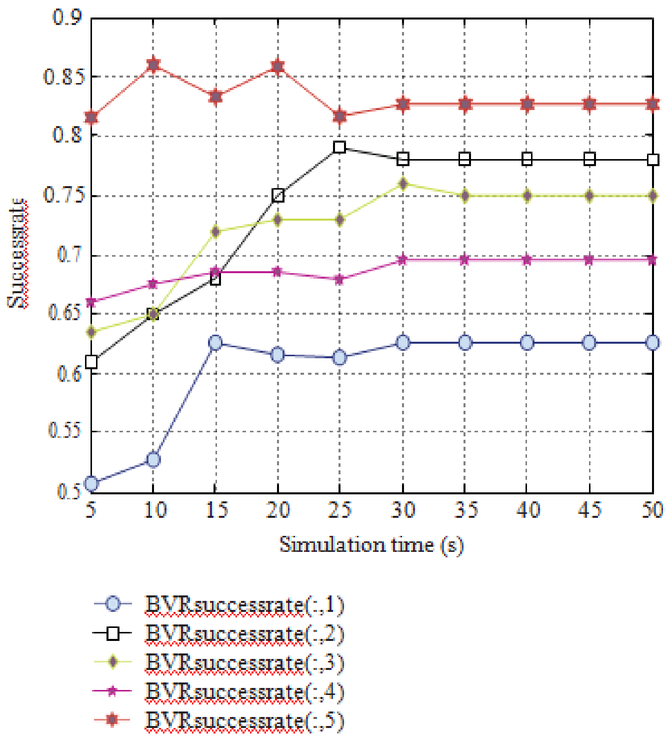

Figure11: Simulation time and success rate assessment

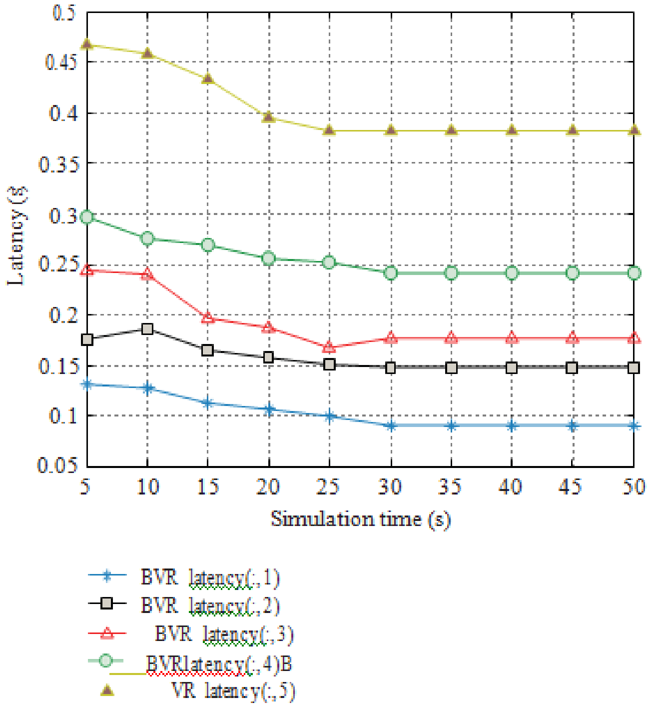

Figure12: Simulation time and delay.

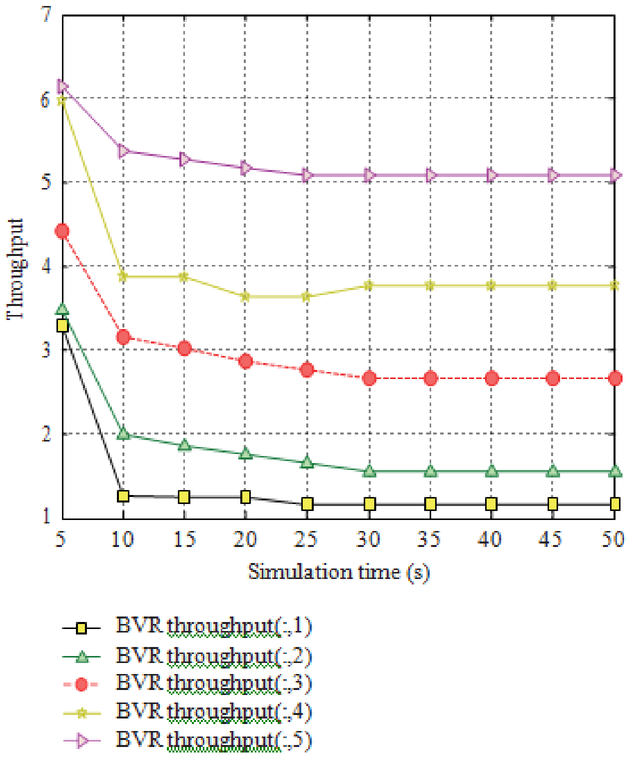

Figure13: The simulation time and throughput assessment

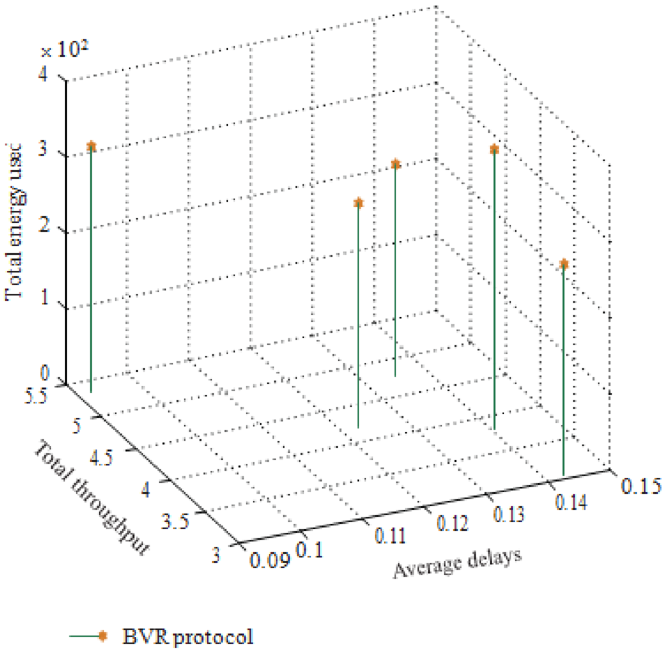

Figure14: Delays—total throughput—total energy used.

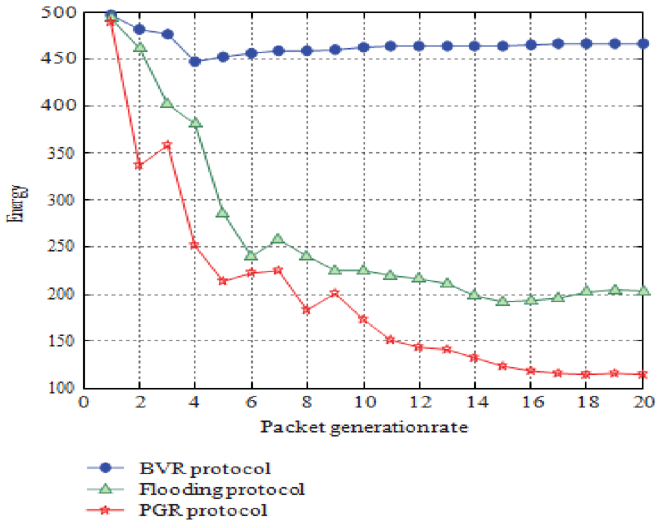

FigURE15: Energy assessment.

F. The size of the Network and its effects of routing metrics on the scalability

This section turns our attention from the scalability to the behavior of the protocols with respect to increasing the number of nodes in the network. The transmission range of each mote is set to 10 units and runs the protocols with 50 to 500 nodes in steps of 50 sensor nodes (motes placed) in a grid. From the observed performance metrics for each of these protocols with increasing of network size, we obtain the following;

- The BVR protocol achieved the best success rate over different network sizes in comparison with PGR and flooding protocols that gave a lower success rate, respectively as shown in the Figure19.
- TheaveragethroughputforBVRwasabout73%over differentnetworksizesasshowninFigure20.While the flooding protocol has about 43% throughput and PGR protocol has about 47% throughput when the number of sensor nodes in the networks is increased.

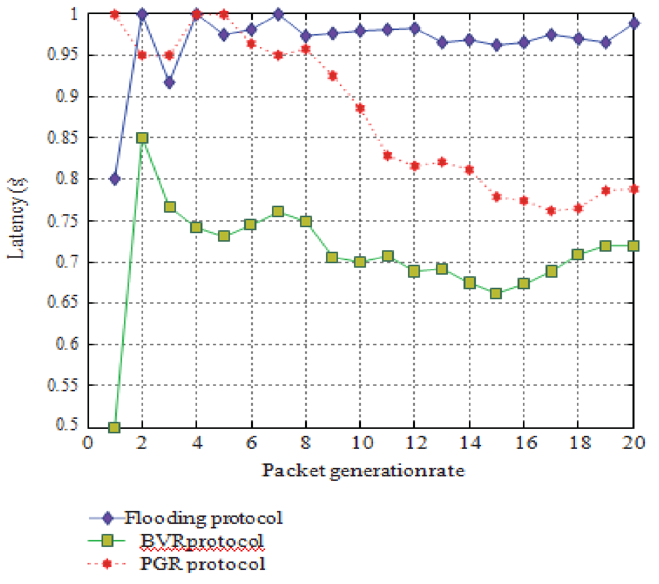

FigURE16: Latency assessment.

- The PGR protocol introduced lower latency than the dump protocol as the network size increased, as shown in Figure 21. Among them, the BVR protocol introduced the lowest latency as the network size increased.
- The power consumption of the BVR protocol was lower than the rest of the protocols based on the increasing number of nodes as shown in Figure 22.

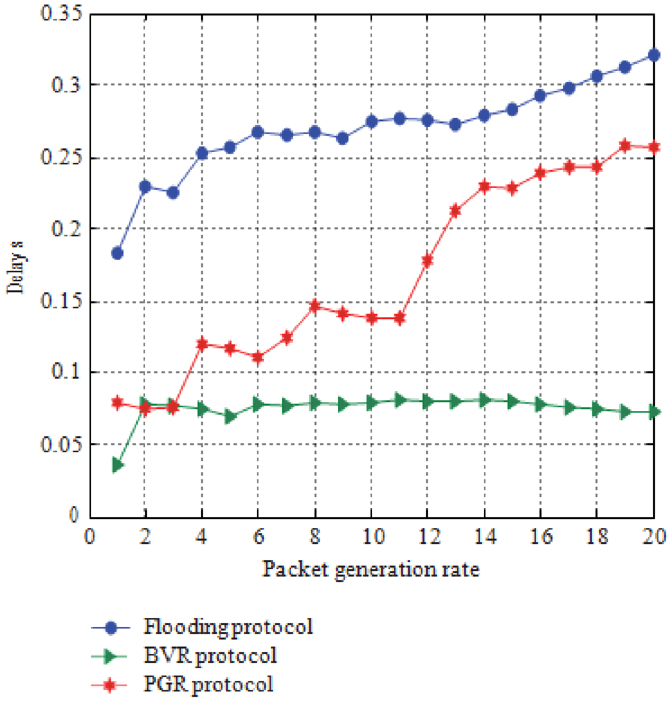

FigURE17: Average packet interruption assessment.

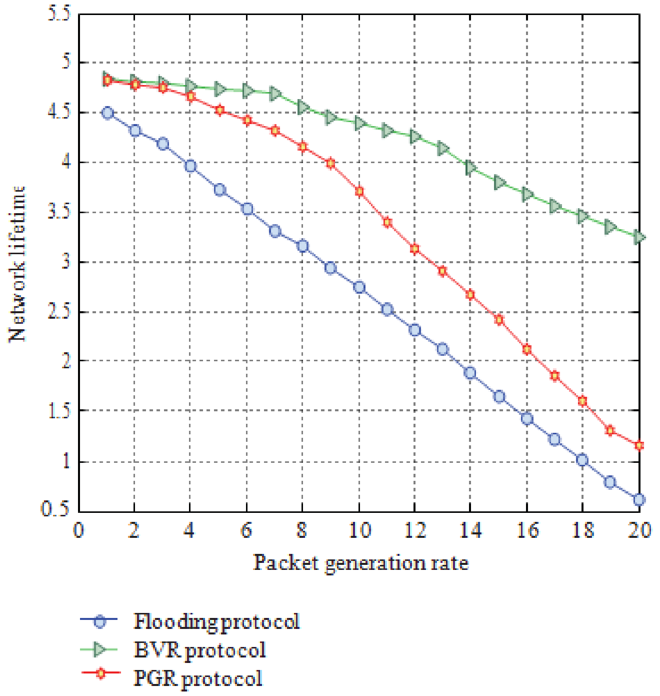

FigURE18: Network life instance assessment.

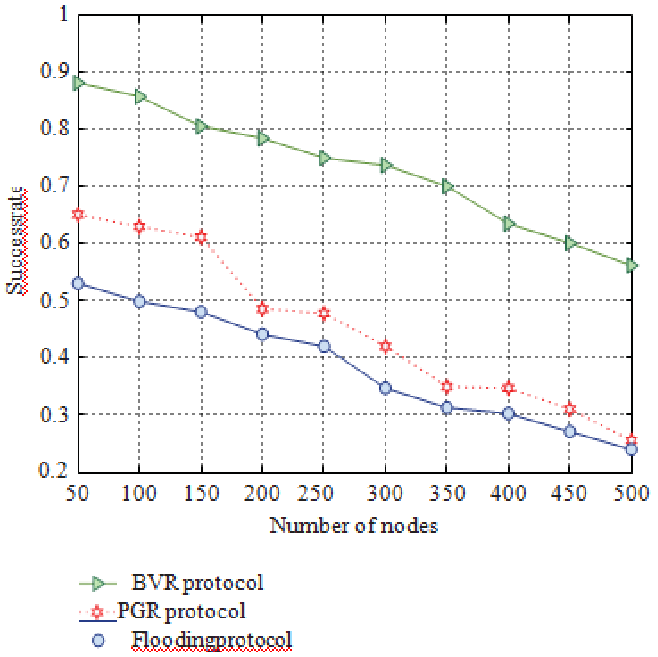

Figure19: Success rate test.

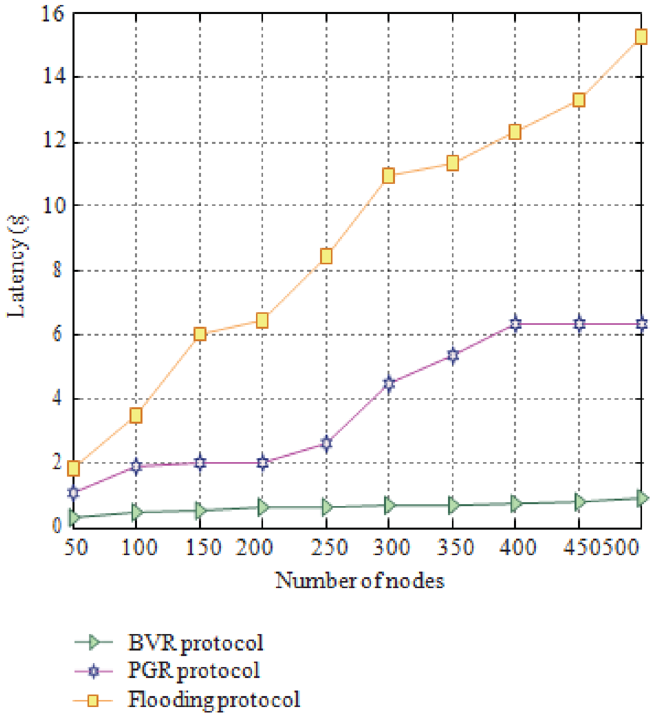

Figure21: Latency test.

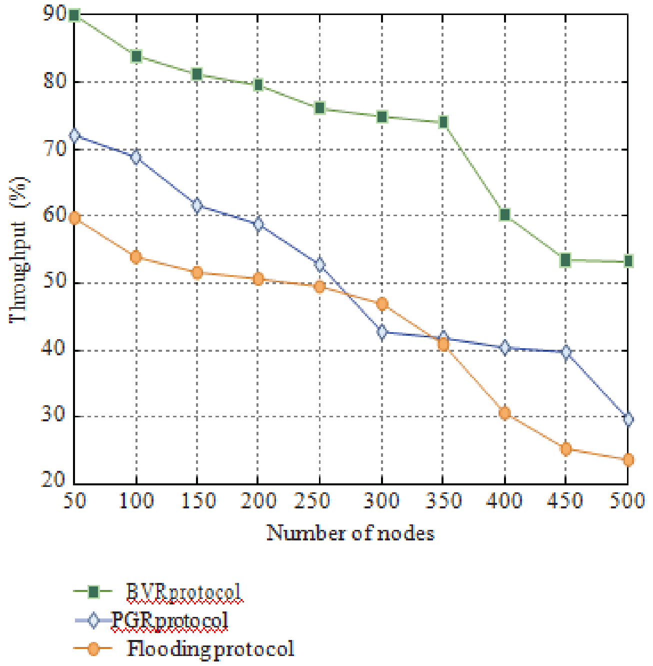

Figure20: Throughput assessment.

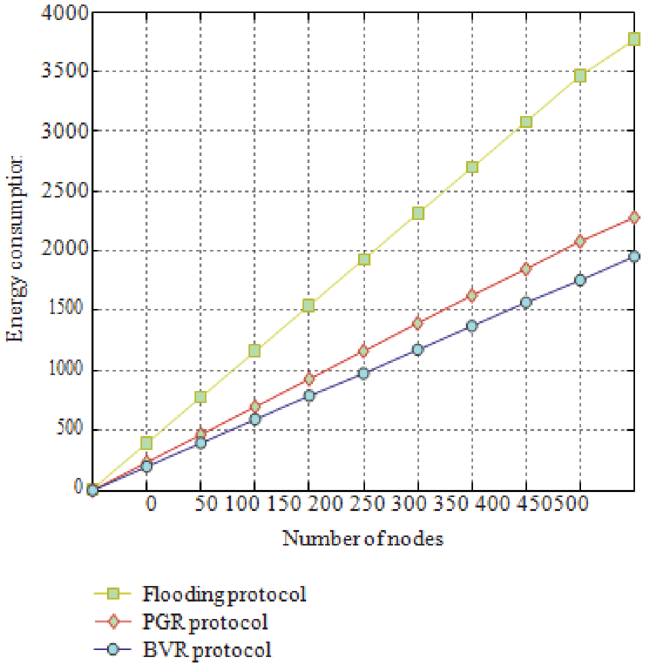

Figure22: The power consumption assessment.

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