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Secure and Efficient Multi-hop Routing for Wireless Mesh Networks

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ABSTRACT

Wireless Mesh Networks (WMNs) are defined as the infrastructure network working with in as ad-hoc mode. In a multi-hop WMNs, it is forever preferable to choose a path with higher throughput between source and destination nodes to utilize the network capacity. Providing security in WMNs has become an important issue over the last few years. In this paper, we propose a new protocol called Secure and Efficient Multi-hop Routing (SEMR) that improves the performance of Wireless Mesh Networks. The main objective of this protocol is to allow the legitimate and link quality intermediate nodes to participate in the routing path. We apply polynomial bivariate key verification to verify the legitimate nodes. The link quality is measured based on the Signal to Noise Ratio (SNR). Simulation results show that the proposed SEMR improves the network performance and reduce the both packet losses and delay.

Keywords: Security, Polynomial bivariate key, Link Quality, Routing, SNR Wireless Mesh Networks.

I. INTRODUCTION

In recent years, Wireless Mesh Networks (WMNs) [3] have attracted wide attention due to their desirable features including self-configuration, reliable service coverage, self-organization, easy maintenance and broadband access especially when multiple channel and radio interference are applied. The components of WMNs are mesh routers, mesh clients and gateways. In WMN, each and every node acts as router (i.e.) the source node send the data to the destination directly or through some intermediate hops. That intermediate hops improve the received signal as well as choose the next forwarding node based on its knowledge about the network. The solutions are as diverse as communication needs, difficult environments such as emergencies, oilrigs, battlefield surveillance, tunnels and high-speed mobile video applications on board public transport or real time racing car telemetry.

Network topologies, number of concurrent flows and interference types established the non-optimal route because of the routing protocol's misbehavior, inaccurate link metric design, interflow interference and their interplay. Link quality metrics and routing algorithms [1] enhances the performance in wireless mesh environments. The network throughput is largely dependent on wireless link quality. The proposed scheme provides better security and efficient routing when selecting the route between source and destination. The polynomial bivariate key is used to verify the legitimate nodes and SNR to estimate the link quality to find the best path.

The rest of the paper is organized as follows. The review of existing algorithm is given in Section 2. In section 3, we propose Secure and Efficient Multi-hop Routing. Simulation results and their discussions are shown in section 4. Finally, section 5 presents the conclusion.

II. RELATED WORKS

The expected transmission count metric (ETX), [2] finds high-throughput paths on multi-hop wireless networks. ETX minimizes the expected total number of packet transmissions essential to send a packet to

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the final destination. The ETX contains the effects of link loss ratios, asymmetry in the loss ratios between the two directions of each link and interference among the successive links of a path.

Identifying High Throughput Paths routing protocols [4] predicts both delay of multi-hop flows and throughput under routing decisions. This scheme can be used to discover high throughput path in a congested network. However this algorithm was not scalable in WMN. Multihop Wireless Mesh Networks [5] assigns weights to individual link based on an Expected Transmission Time (ETT) of a packet over the link. ETT is a function of the loss rate and the bandwidth of the link. Source Based Routing (SBR) [6] is the combination of packet losses, intraflow and interflow interferences and load gateways selects the best path to reach selected gateways. This scheme improves the network performance. SBR uses a combination of routing metrics resulting in significantly less packet losses or retransmissions and shorter delays. However, this scheme does not provide the security to mesh nodes.

A Novel Routing Metric for Multi-Radio [7] selects the path with minimum cost and expected end-to-end delay in a multi radio WMN. This approach increases the wireless network capacity and it describes the path more accurately. Two Soft Computing Based Approaches [8] designed a routing scheme that is mainly based on the use of fuzzy logic by considering link cost measure, such as the delay, throughput, and jitter, to evaluate near shortest paths in WMNs. Big Bang Big Crunch (BB-BC) and Biogeography Based Optimization (BBO) approaches enumerated shortest or near short paths. Both the algorithms have low computational time and high convergence speed. These routing algorithms find the optimal shortest path taking into account three most important parameters of network dynamics.

Adaptive Situation Aware Load Balance Scheme [9] proposed dynamic load balance routing. This adaptive routing provide more efficient path and decrease the effect of interference. This scheme maintains the optimal path and avoid changes path too frequently. Multi Hop Effective Bandwidth (MHEB) [10] reveals the impact of interference on the capacity of a path, that measured by effective bandwidth. The MHEB considers both inter-flow and intra-flow interference, channel utilization, link loss rate and bandwidth of sub-path. However, it does not provide guaranteed optimal system throughput. Availability Performability Tradeoff in Wireless Mesh Networks [11] scheme maximizes both availability and performability. Performability is considered as opposed to average case throughput performance, there does not exist a transmission power or node density that can maximize both availability and performability. This scheme develops algorithm based on intelligent state sampling which can calculate both the quantities with reasonable accuracy. A Secure and Reliable Routing Protocol [12] proposed reliability and security route in a hostile environment by avoiding the use of unreliable intermediate nodes. A mesh client beyond the wireless transmission range of the mesh router may still discover a secure route to the mesh router. This protocol establishes a shorter route with a higher success rate because it considers both symmetric and asymmetric links with a relatively low computation overhead.

III. PROPOSED METHOD

Generally, the WMNs use the hybrid routing protocols to handle the traffic flow in the Mesh network. However, the hybrid protocols did not consider the security related problems. Therefore, we propose Secure and Efficient Multi-hop Routing for Wireless Mesh Networks (SEMR) aiming to maximize the throughput and improve the network security. In this, we are utilizing Polynomial bivariate key predistribution scheme to provide authentication and link quality measurement to discover the best path in WMN.

When a source wants to send the data to the destination through the intermediate nodes, it first broadcasts a Route Request (RREQ) message. This message contains the broadcast id, destination id, destination sequence number, source id, source sequence number and hop count. When a node receives, this RREQ then it send the RREP message back to the source node. This RREP message contain destination id, destination sequence number, Signal to Noise Ratio (SNR) value with polynomial bivariate key. The polynomial bivariate key is calculated for every link between the node and is given below.

$$f(u,v) = \sum_{i,j=0}^{n} a_{ij} u^i v^j \tag{1}$$

Where the coefficients a_{ij} $(0 < i, j < n)$ are randomly chosen from a finite Galios field and u,v represent the node.

The polynomial bivariate key is a symmetric property like

$$f(u,v) = f(v,u) \tag{2}$$

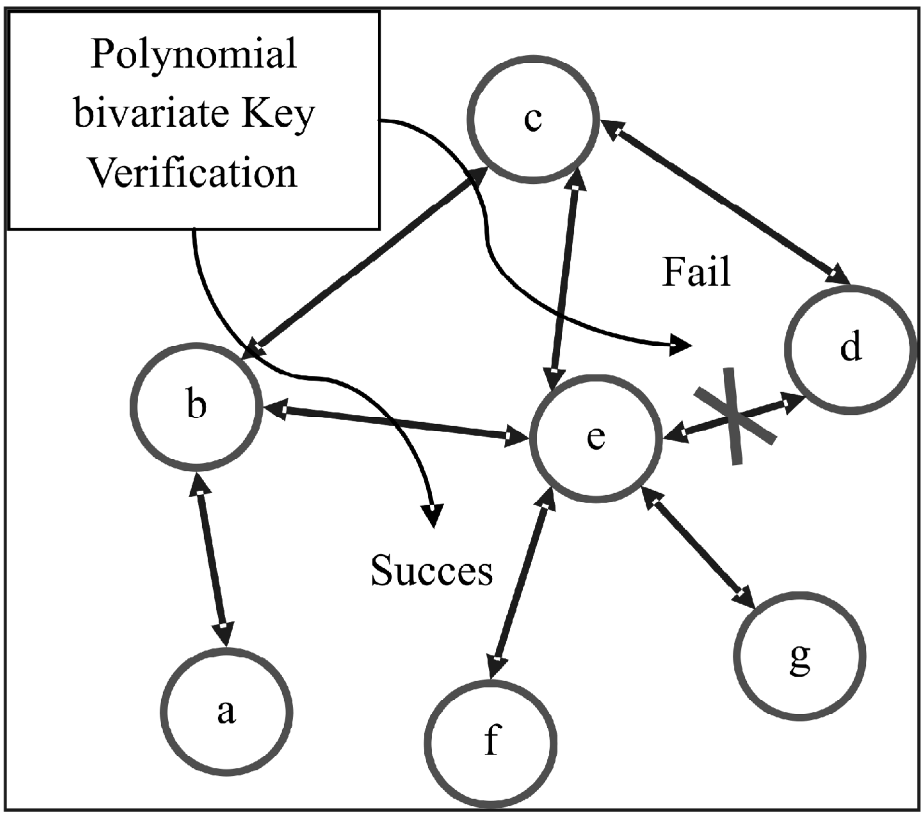

Figure 1: Polynomial Bivariate Key Verification

Figure1 show the polynomial key verification among nodes in WMN. By using polynomial bivariate key, the source analyzes the key values of each node. After identify that both are having the same polynomial then the source node checks the SNR value. This SNR has been used as a link quality as follows.

$$SNR = \beta \times SNR + (1-\beta) \times SNR_{new} \tag{3}$$

Where $\beta \rightarrow 0.75$

$SNR_{new} \rightarrow$ Most recent SNR value

The SNR value is used to determine the link throughput for finding the best route path selection in WMN. Finally, the data packets are sent through the highest link quality node.

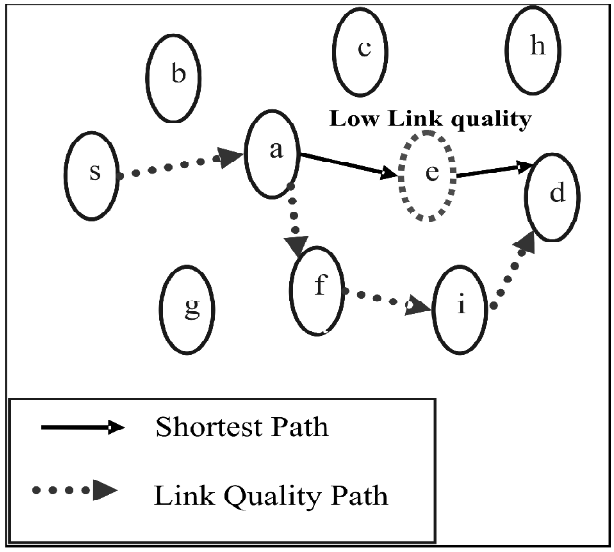

Figure 2: Link quality based Route Selection in WMN

In figure 2, the route from source to destination is s-a-e-d. But the node *e*, the link quality is low. Therefore, the proposed scheme finds the new route s-a-f-i-d. The a-e-d path is replaced by a-f-i-d, thus the packets are received successfully. This established path is enhancing the network performance.

The figure 3 indicates the working flow of the proposed scheme. Initially the source verifies the intermediate node and is authenticated based on polynomial bivariate key. If the key matches, then the

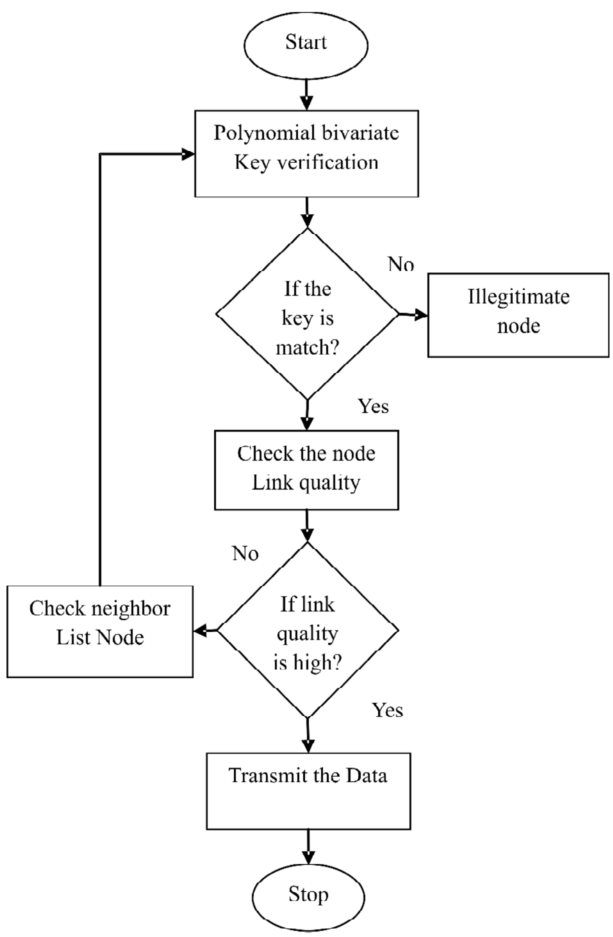

Figure 3: Flowchart of the Proposed Scheme

source node checks the link quality of the node. Otherwise, the source send notification message to the all nodes. The link quality is measured based on the SNR value. The highest link quality node is selected as the next hop node. Finally, the source sends the data to destination through the highest link quality nodes.

IV. SIMULATION ANALYSIS

The performance of the proposed scheme is analyzed by using the Network simulator (NS2). The NS2 is an open source programming language written in C++ and OTCL (Object Oriented Tool Command Language). NS2 is a discrete event time driven simulator which is used to mainly model the network protocols. The nodes are distributed in the simulation environment. The parameters used for the simulation of the SEMR are tabulated in table 1.

The simulation of the proposed scheme has 50 nodes deployed in the simulation area 700×700. The nodes are communicated with each other by using the communication protocol User Datagram Protocol (UDP). The traffic is handled using the traffic model CBR. The radio waves are propagated by using the propagation model two ray ground. All the nodes receive the signal from all direction by using the Omni directional antenna. The performance of the proposed scheme is evaluated by the parameters packet delivery rate, packet loss rate, average delay and throughput.

Table 1
Simulation parameters of SEMR

Parameter	*Value*
Channel Type	Wireless Channel
Simulation Time	50 s
Number of nodes	50
MAC type	802.11
Traffic model	CBR
Simulation Area	700×700
Transmission range	250m
Network interface Type	WirelessPhy

4.1. Packet Delivery Rate

The Packet Delivery Rate (PDR) is the ratio of number of packets delivered to all receivers to the number of data packets sent by the source node. The PDR is calculated by the equation 4, where n represents the number of nodes in the WMN.

$$PDR = \frac{\sum_0^n Packets\ Received}{\sum_0^n Packets\ Sent} \tag{4}$$

The figure 4 shows the PDR of the proposed scheme SEMR is higher than the PDR of the existing method SBR. The greater value of PDR means the better performance of the protocol.

4.2. Packet Loss Rate

The Packet Loss Rate (PLR) is the ratio of the number of packets dropped to the number of data packets sent. The formula used to calculate the PLR is given in equation 5.

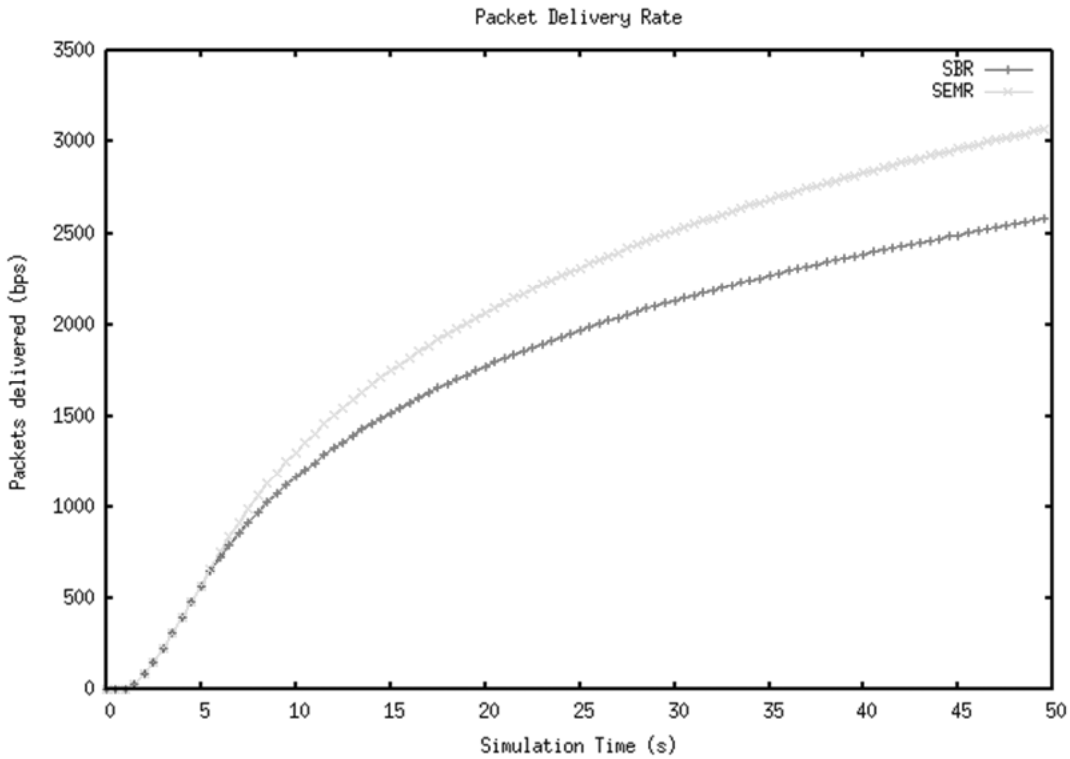

Figure 4: Packet Delivery Rate

$$PLR = \frac{\sum_0^n Packets\ Dropped}{\sum_0^n Packets\ Sent} \qquad (5)$$

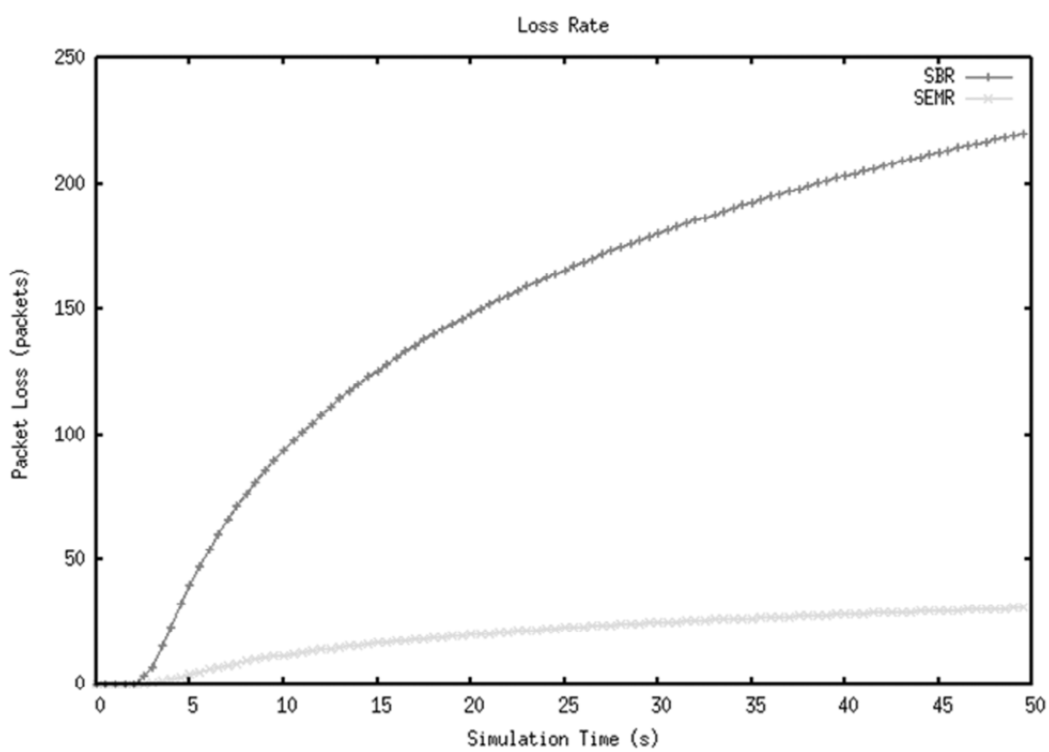

Figure 5: Packet Loss Rate

The PLR of the proposed scheme SEMR is lower than the existing scheme SBR in Figure 5. Lower the PLR indicates the higher performance of the network.

4.3. Average Delay

The average delay is defined as the time difference between the current packets received and the previous packet received. It is measured by the equation 6.

$$Average\ Delay = \frac{\sum_0^n Pkt\ Recvd\ Time - Pkt\ Sent\ Time}{n} \quad (6)$$

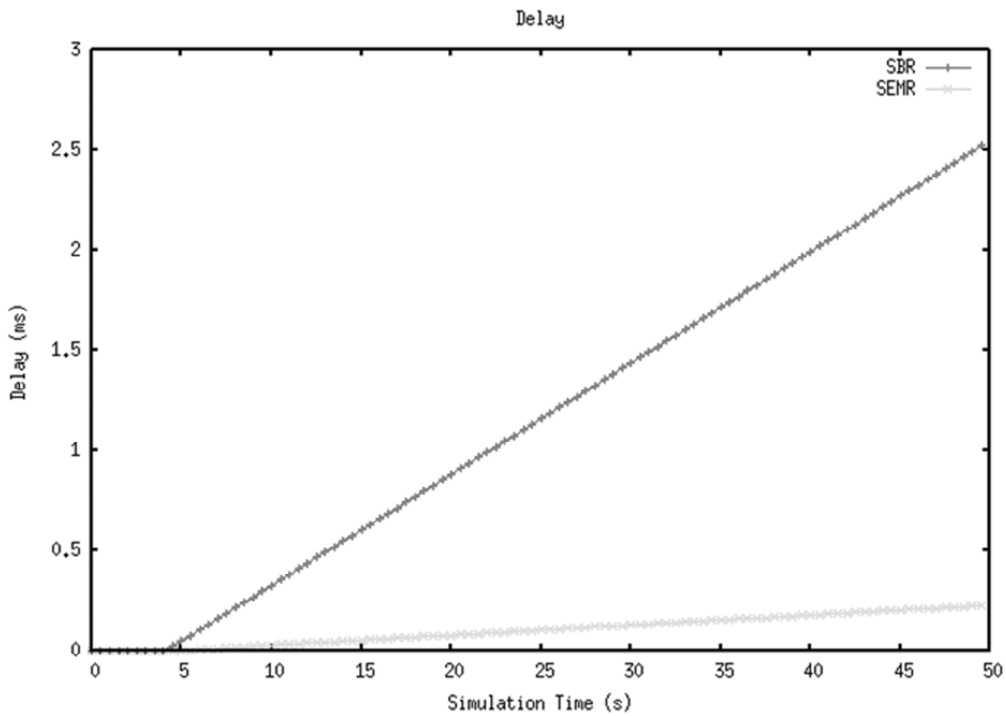

Figure 6: Delay Rate

Figure 6 shows that the average delay value is low for the proposed scheme SEMR than the existing scheme SBR. The minimum value of delay means that higher value of the throughput of the network.

4.4. Throughput

Throughput is the average of successful messages delivered to the destination. The average throughput is estimated using equation 7.

$$Throughput = \frac{\sum_0^n Pkts\ Received\ (n) * Pkt\ Size}{1000} \quad (7)$$

Figure 7 shows that proposed scheme SEMR has greater average throughput when compared to the existing scheme SBR.

V. CONCLUSION

In this paper, we concentrate on the routing and security in Wireless Mesh Networks. We propose the new protocol SEMR to enhance the network performance and provide reliable connectivity. In this scheme, we

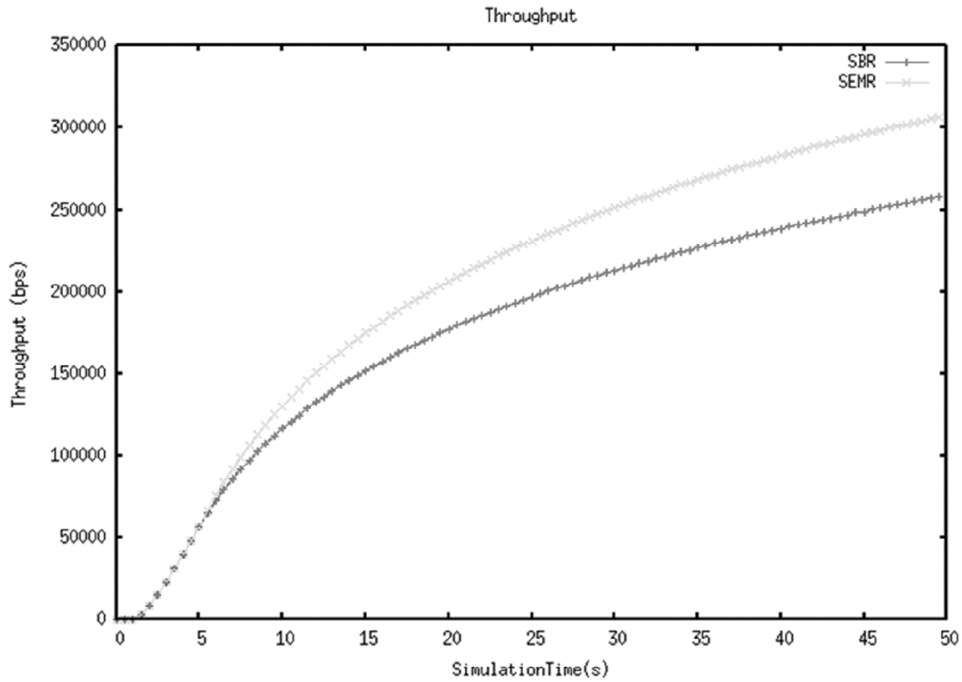

Figure 7: Throughput

use polynomial bivariate key algorithm for verifying the legitimate nodes for secure data transmission. The node link quality is measures based on the SNR to guarantee optimal path selection. The simulation results demonstrate that the SEMR provide guaranteed packet delivery rate and reduces the both packet loss rate and delay in WMNs.

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