Bandwidth Aware Routing with SIC through Genetic Algorithm in MANET

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Abstract: Wireless Networks includes a larger advantage in today's communication application like environmental, traffic, military, and health observation. To realize these applications it's necessary to possess a reliable routing protocol. In this research, the main focus is on the design of genetic algorithm routing protocol based on bandwidth aware Successive Inference Cancellation (SIC) aiming at achieving high overall throughput compared to it of the hop count routing. A novel bandwidth routing mechanism is proposed, where all the cluster head nodes in network estimate bandwidth periodically. Successive Interference Cancellation (SIC) is an innovative physical layer technique that allows the receiver to decode composite signals from multiple transmitters consecutive. The introduction of SIC improves bandwidth of the route from source to destination node. The proposed algorithm works in two stages: in first stage the whole network is divided into clusters and cluster head are selected on the basis of genetic algorithm. After selection of cluster head we then move towards the second stage. In the second stage, the route is selected among cluster head by using the concept of bandwidth aware SIC. Those nodes having minimum SIC value will be selected for data forwarding from source to destination. A comparison of BASIC and GA-BASIC routing algorithm is analyzed in this report and it is concluded that the GA-BASIC routing algorithm has improves the path bandwidth and results in high throughput.

Keywords: Genetic Algorithm; Cluster Head; Multihop Wireless Networks; Available Bandwidth; Successive Interference Cancellation; Throughput.

Introduction

The recent evolution of ad hoc wireless technologies has allowed mobile ad hoc networks (MANETs) to construct spontaneous connections among mobile devices with none infrastructure [1, 2]. Moreover, with the emergence of sensor-enabled smart mobile devices, Manets became a vital part within the infrastructure of smart city and internet of Things (IoT) situations as a result of individuals with smart devices will freely and dynamically kind a self-configuring MANET to send, receive and share data in an exceedingly restricted zone (as shown in figure 1.2) [3]. In an exceedingly such a smart environment, MANETs, Wireless sensor Networks (WSNs) and Wireless Mesh Networks (WMNs) represent key technologies providing many IoT applications and services to users. moreover MANETs have found a range of applications in health care, battlefield communications, disaster recovery, crisis management services education organizations, ad hoc cooperative computing, social activities and conference halls.

Despite the attractive applications of MANETs, these systems still face several challenges and constraints that need more investigation before the widespread commercial deployment of MANETs. The most constraints that may have an effect on Manet design are as follows: (1) the limited energy and lifetime of the battery, quality of service (QoS),infrastructure-less and autonomous configuration, dynamic network topologies, the mobility of nodes, wireless link reliability, variation in node capabilities, multi-hop routing scalability, multicast support and security threats [4]. Therefore, routing protocol plays a major role in such networks, and there remains ought to consider the on top of constraints of MANETs within the development of latest routing protocols to modify the efficient forwarding of packets over a wireless medium, primarily once the source and destination are non-neighboring nodes. The routing protocol should choose the best route between pairs of source–destination nodes in terms of energy consumption and QoS metrics like available link bandwidth, average end-to-end delay, packet losses and average noise. The reminder of this paper proceeds as follows.

Various approaches to high throughput and bandwidth aware multi-hop routing algorithms in ad-hoc have been studied and derived with the aim to reduce the connection set up latency, delay and bandwidth and to ensure guaranteed performance level to the QoS sensitive applications. Multipath routing is more promising in ad hoc networks since it provides additional features like load balancing, fault-tolerance, higher throughput etc., to ensure QoS assurance in ad hoc networks.

Most of the routing protocols that have been proposed for mesh and ad hoc networks are unipath, which means only a single route is used between a source and a destination node. The main goal of multipath routing is to allow the use of several good paths to reach destinations, not just the best path. This should be achieved without imposing excessive control overhead in maintaining such paths.

The availability of multiple paths between a source and a destination can be used to achieve the following benefits:

Fault tolerance: introducing redundancy in the network or providing backup routes to be used when there is a failure [11], are forms of introducing fault tolerance at the routing level in mesh networks. To this end, some techniques may be applied like packet salvaging [12, 13], which consists in modifying the route of a packet if the actual route is broken.

Throughput enhancement: in a mesh network, some links can have limited bandwidth. Routing along a single path may not provide enough bandwidth for a connection. Therefore, using simultaneously multiple paths to route data can be a good approach to satisfy the bandwidth requirement of some applications. By increasing the throughput, a smaller end-to-end delay is achieved and quality of service is improved [14].

Section II presents the previous work in the field of bandwidth aware routing protocol based on Successive Inference Cancellation (BASIC). Section III explains the system methodology and illustrates the used techniques Section IV explains the experimental results of the proposed methodology. Conclusion and future work are illustrated in section V.

Related Works

This research presented a non-invasive system utilizing the Runzi Liu et al. [1] proposed a design of bandwidth-aware routing protocol with SIC, aiming at achieving high overall end-to-end throughput. We develop an SICable condition for a routing protocol to identify beneficial SIC opportunities that improve spatial reuse without impacting transmission quality. To further explore the benefits of SIC, we formulate the problem of SIC-aware path bandwidth computation as a linear program, and design a distributed heuristic algorithm with polynomial complexity. A routing metric capturing the benefit of SIC in terms of bandwidth and network resource is proposed, by which our routing protocol can choose a path satisfying the bandwidth requirement of the current flow and reserving more network resource for the subsequent ones.

Runzi Liu et al. [2] developed a distributed routing protocol that exploits the benefit of SIC and takes interference into consideration. The main contributions are as follows. First, we introduce the concept of guard zone to show not all SIC opportunities are beneficial to the overall network throughput, and then define an SICable condition by which SAR can discover the beneficial SIC opportunities.

Second, the benefits of SIC that improves the overall end-to-end throughput is captured in terms of reduction in spatial resource consumption and bandwidth efficiency improvement. Finally, an SIC aware routing metric is designed which takes into account the effects of both SIC and interference. Using this metric, our routing protocol can discover the high throughput path with less spatial resource consumption, and therefore enhance the overall network throughput.

Multi-path routing improves end-to-end throughput through parallel transmission with multiple paths between source and destination, thus satisfying the bandwidth requirement of multimedia applications. Wenjing Yang et al. [3] studies the relationship between the number of non-interference parallel paths and the end-to-end throughput, and then concludes that routing can achieve the optimal performance when the number of parallel paths is 2.

Based on the analysis, this research presents a Bandwidth aware Multi-path Routing (BMR) protocol, which can find two disjoint parallel paths between source and destination based on the available bandwidth restriction. In BMR, the available bandwidth of node is obtained based on a cross-layer mechanism, which can provide a metric for routing discovery. Therefore, it is more suitable for multimedia traffic than existing protocols.

Multi-path routing protocols for MANET are deemed superior over conventional single-path routing protocols as the former reduce end-to-end delay, increase reliability and provide robustness.

However, the shortest path routes resulting from shortest multi-path routing, such as AOMDV, cause the area congested and thus its effectiveness is decreased. Pattana Wannawilai and Chanboon Sathitwiriyawong [4] proposes a novel Ad hoc On-demand Multipath Distance Vector with Sufficient Bandwidth Aware (AOMDV+SBA) routing protocol which significantly improves the performance of the original AOMDV routing protocol by discovering better routes to avoid congestion. Furthermore, in terms of low-to-medium traffic load, its performance is quite close to the unique AOMDV routing protocol and the value of its properties is maintained.

Zhi Zhang et al. [5] proposed an approach in which multiple node-disjoint paths are formed during the route discovery process and are actively maintained. The detector packets determine the accessible bandwidth of each node along the path. The approximate bandwidth of a node is estimated based on the bandwidth consumption information indicated in the modified HELLO messages.

The estimated bandwidth is used as the metric to choose the primary route. Simulation results show that packet delivery rate increases a lot, and end to end delay and jitter decrease significantly, while the overhead is not increase too much, compared with original single path routing protocol.

Marina and Das [6] have proposed a multipath version of the popular AODV protocol called AOMDV. It is designed primarily for highly dynamic ad hoc networks where frequent link failures and route breaks occur. With multiple redundant paths, new route discovery is needed only when all paths to the destination fail, unlike single path AODV.
The AOMDV algorithm finds multiple loop free link disjoint routes in the MANET and performs better in terms of delay, routing load and route discovery time compared to the single path version. However these multiple paths need not satisfy the QoS requirements of the flow as the intermediate nodes taking part in the multiple paths are not selected based on their QoS capabilities.
Ivascu et al. [7] presented an approach based on a mobile routing backbone (MRB) for supporting QoS in MANETs. The authors aimed to identify the nodes with capabilities and characteristics that would enable them to take part in the MRB and efficiently participate in the routing process. This approach improves network throughput and packet delivery ratio by directing traffic through lowly congested regions of the network that are rich in resources.
Liao et al. [8] proposed a multipath QoS routing protocol which searches for multiple paths for the QoS route, where the multiple paths refer to a network with a source and a sink satisfying a certain bandwidth requirement. The multiple paths collectively satisfy the required QoS. The protocol is suitable for ad hoc networks with very limited bandwidth where a single path satisfying the QoS requirements is unlikely to exist.
Reddy and Raghavan [9] proposed a scalable multipath on demand routing protocol (SMORT), which reduced the routing overhead incurred in recovering from route breaks by using secondary paths. SMORT computes fail-safe multiple paths, which provide all the intermediate nodes on the primary path with multiple routes to the destination. The proposed protocol is scalable, and performs better even at higher mobility and higher traffic loads, when compared to the disjoint multipath routing protocol (DMRP) and AODV routing protocol.
Rishiwal et al. [10] proposed a QoS based Power Aware Routing (Q-PAR) protocol for MANETs by modifying the DSR protocol. Q-PAR selects an energy-stable and QoS constrained end-to-end path from source to destination. According to the results presented, the protocol showed increased network life time, improved packet delivery ratio and reduced average packet delay.
Routing algorithms have a major part in communicating information over a system. Routing protocols has two noteworthy arrangements are unipath and multipath.
J Seetaram and P Satish Kumar [11] assesses execution of an on-demand multipath routing protocol called Adhoc On-demand Multipath Distance Vector (AOMDV) routing. This paper suggests an energy-aware Genetic Algorithm (GA) based Multipath Distance Vector Protocol. GA has been viewed as one of the meta-heuristic strategies created to take care of the optimization issues utilizing the simulation of the conduct of the hereditary operators.
Walaa Gad and Tamer Abdelkader [12] motivates for using fuzzy-logic as an inference system to solve the routing problem. In this paper, we propose a fuzzy-based routing protocol for M-MANET (FRPM). The protocol works in a hop-by-hop manner, which uses some locally measurable parameters to produce a decision either to select the contacting node as the next hop or not.
Shaohe Lv et al. [13] studied the greedy scheduling based on the physical model in a wireless network with successive interference cancellation (SIC). Due to the accumulation effect and sequential detection nature of SIC, it is difficult to evaluate the link interference for scheduling. As a result, they focus on time slot selection, define the tolerance margin to measure the saturation of a link set, and present two efficient heuristic policies to choose the best slot for a given link.
QoS is an agreement to supply secure services, like bandwidth, delay, delay jitter, and packet delivery rate to users. Supporting quite one QoS constraint makes the QoS routing problem NP-complete. Therefore, solely take into account the bandwidth constraint once studying QoS-aware routing for supporting real-time video or audio transmission. It's planned a QoS-aware routing protocol that either provides feedback regarding the accessible bandwidth to the application (feedback scheme), or admits a flow with the requested bandwidth (admission scheme). Both the feedback scheme and also the admission scheme need information of the end-to- end bandwidth available on the route from the source to the destination. Thus, bandwidth estimation is that the key to supporting QoS. This work focuses on exploring totally different ways to estimate the available bandwidth, incorporating a QoS-aware scheme into the route discovery procedure and providing feedback to the application through a cross-layer design.
Pattana Wannawilai and Chanboon Sathitwiriyawong [15 proposes a unique AODV with sufficient bandwidth Aware (AODV+SBA) routing protocol that considerably improves the performance of on-demand routing protocols by discovering higher routes to avoid congestion and reducing excessive routing overhead. The ns-2 simulation results illustrate the development of network performance and stability by reducing data packet delay and routing overhead and increasing packet delivery ratio, underneath high traffic load. Moreover, just in case of low-to-medium traffic load, its performance is close to the favored AODV routing protocol and also the quality of its properties is maintained.

Proposed Methodology

This section discusses about the working of proposed hybrid bandwidth aware routing protocol based on genetic algorithm for multihop routing in Ad-hoc. The proposed algorithm is based on Bandwidth Aware Successive Interference Cancellation

(BASIC). In routing algorithm is proposed which adds computation of SIC parameters and if the links satisfies the bandwidth criteria then it is chosen as the next forward link during the routing process. The Advantages of Proposed Approach are End to End Delay is less, Energy consumption is reduced due to fact that the routes that are discovered are very less and also control packets exchanged is less, The algorithm takes SIC bandwidth criteria in order to pick the forwarding nodes or forwarding link hence the throughput is high because the route chosen is bandwidth aware. The proposed algorithm is discussed in detail below (see Figure 1).

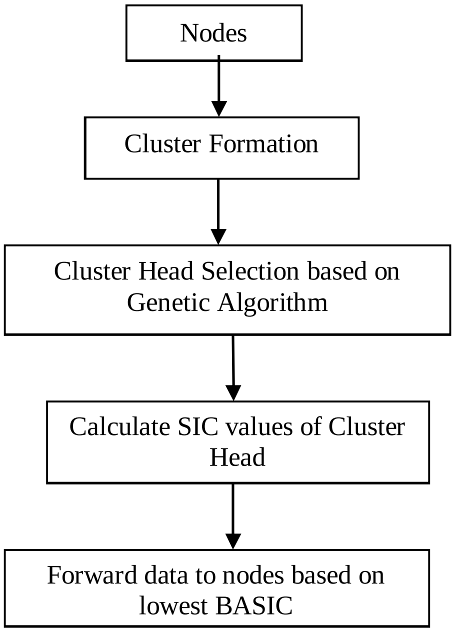

Figure 1 Proposed Methodology

The proposed methodology works in two basic steps:

Cluster Formation and Cluster Head Selection

To adopt hybrid routing schemes, ad hoc network is usually organized into a hierarchical structure of multiple virtual subnets, which form a high-level and relatively stable backbone network. Clustering is a practice to dynamically assemble together nodes in a network which are logically separated or overlapping entities termed as clusters, each of which consists of a distinguished node called cluster head (CH), and other member nodes.

Cluster Head are selected according to the Genetic Algorithm (GA) as a dynamic technique to find optimum states. A genetic algorithm is categorized as a global search heuristic algorithm in which an optimal solution is estimated by generating different individuals. This algorithm is comprised of procedures such as focused fitness functions.

The main objective of the proposed algorithm is to generate bandwidth-aware clusters for randomly deployed sensor nodes associated with a cluster head. CH receives messages from the cluster members and transmits the aggregated messages to a distant base station (BS).

In this phase, the sensor nodes self-organize into a new set of clusters based on genetic algorithm. In proposed routing algorithm genetic algorithm based cluster head selection process is designed as shown in figure 2.

Data routing based on Bandwidth Aware Successive Interference Cancellation

Many works have been carried out on high throughput routing with Interference Cancellation. In this report High Throughput SIC routing algorithm is proposed which adds computation of SIC parameters and if the links satisfies the bandwidth criteria then it is chosen as the next forward link during the routing process. Also the number of routes discovered is drastically reduced.

The Advantages of Proposed Approach are End to End Delay is less, Energy consumption is reduced due to fact that the routes that are discovered are very less and also control packets exchanged is less. The algorithm takes SIC bandwidth criteria in order to pick the forwarding nodes or forwarding link hence the throughput is high because the route chosen is bandwidth aware.

The SIC routing algorithm first finds the one neighbor cluster head and then each of the cluster head acts like a source node. After finding the neighbor sets the cluster heads which has lowest SIC value is chosen.

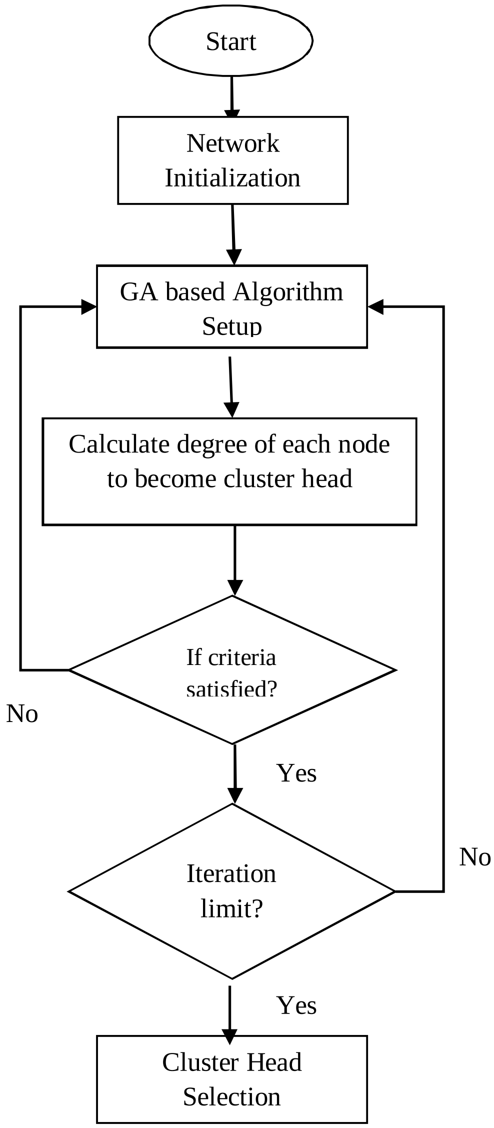

Figure 2 Genetic algorithm based cluster head selection

This process is repeated until threshold time expires or until destination is reached. Once the time expires min hop routing algorithm triggers which finds the ultimate link to destination. Like that multiple routes are discovered. Then the route which has lowest SIC value is chosen as the best route.

In the Figure 3, Source Node, Destination Node and Transmission Range acts and Threshold time as an input. The Source cluster head Node will find the set of cluster head nodes within transmission range known as neighbor cluster head nodes.

If the neighbor cluster head nodes have the destination cluster head node then stop the process. If the neighbor cluster head nodes do not have the destination cluster head node then pick one of the neighbor as the next forward node which has lowest SIC value. Check the Threshold Time. If the time has expired continue. If threshold time expires then execute Min Hop Algorithm.

$$SIC = \frac{P(tx)d^{-\alpha}(i,j)}{\sum_{k=1}^{N} P(tx)d^{-\alpha}(i,j) + \sigma^2}$$

Where, *P(tx)* = Transmission Power
$d^{-\alpha}$ (i,j) = Distance between node i and j
σ = Power level of noise
α = Path loss components

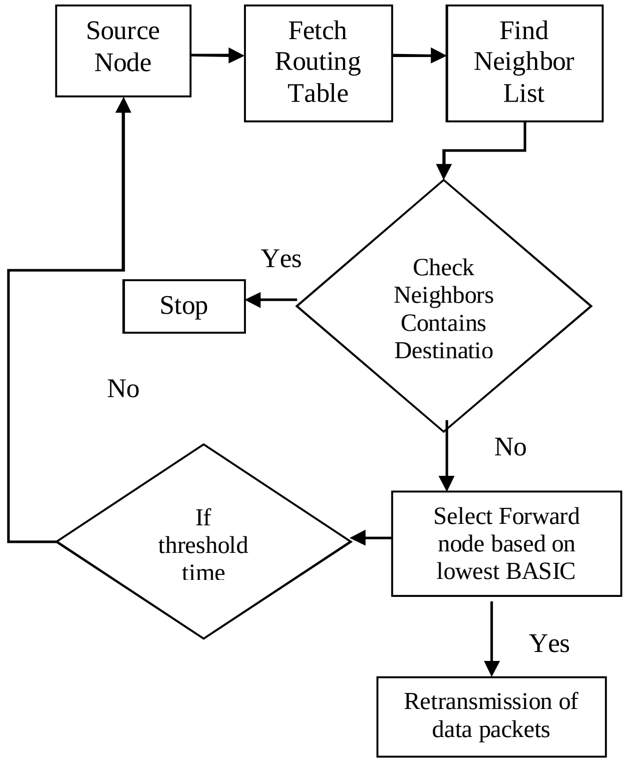

Figure 3 Bandwidth Aware Successive Interference Cancellation

Result Analysis

This section shows the Performance evaluation of proposed Genetic Algorithm based multihop Routing protocol with Bandwidth-Aware Successive Inference Cancellation (GA-BASIC) is discussed. In this proposed algorithm, a genetic algorithm based cluster routing protocol is designed using SIC parameter to extend the lifetime of the network. First of all there is a task to form cluster. There is a trade-off between energy consumption and distance parameters because making large numbers of clusters shortens the distance between the sensor member nodes and also corresponding CH. Any cluster has at least one CH, which consumes much energy. In other words, creating many clusters increases energy consumption level rather than decreasing of distance. Because of this, we use the ratio of total energy consumptions to the total distances of nodes in order to achieve average amount of used energy for every node.

Table 1. Time Comparison of Route Discovery

No. of Nodes	**No. of Cluster Head**	**Time Elapsed in Data Transmission**		
		GA-BASIC (in sec)	**AODV (in sec)**	**BASIC (in sec)**
50	14	1.672921	2.419409	2.250593
60	14	1.800644	2.509071	2.380689
70	18	1.979664	2.537227	2.461978
80	20	2.233246	2.541931	2.842683
90	24	2.544679	2.557103	2.896468
100	26	2.8053	2.580661	3.433055
Average Time Elapsed (in sec)		2.172742333	2.524233667	2.710911

The proposed algorithm is to generate bandwidth-aware clusters for randomly deployed nodes associated with a cluster head. CH receives messages from the cluster members and transmits the aggregated messages to a distant base station (BS).
Table 1 and figure 4 shows the time analysis of proposed algorithm (GA-BASIC), BASIC algorithm and AODV algorithm for multihop routing protocol.

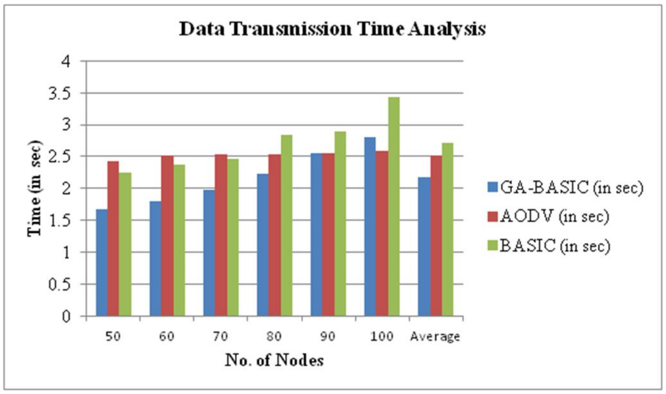

Figure 4 Time Comparison of Route Discovery

The comparative analysis shows that the proposed algorithm based on clustering concept shows that number of routes is lesser in GA-BASIC criteria than other algorithms and thus requires less data transmission time.
To further understand the performance gain, we define SIC throughput value as total bandwidth used in the network for data transmissions to the total number of bandwidth allotted for data transmissions in the network.

Table 2. Comparative Analysis of SIC Throughput

No. of Packets	GA-BASIC Throughput	BASIC Throughput
5	99.97%	99.84%
25	99.84%	98.77%
50	99.38%	97.31%
75	99.29%	95.58%
100	98.85%	96.57%
Average Value	99.47%	97.61%

Table 2 and Figure 5 shows the SIC throughput of the two different routing algorithms. We can see BASIC has the lower throughput value as compared with the GA-BASIC throughput value because in BASIC algorithm, SIC value of each and every nodes are calculated and then data is routed by finding route have minimum SIC value required.
Compared with the throughput performance of these protocols, it can be find that an SIC aware routing protocol is indispensable for improving end-to-end throughput with SIC.

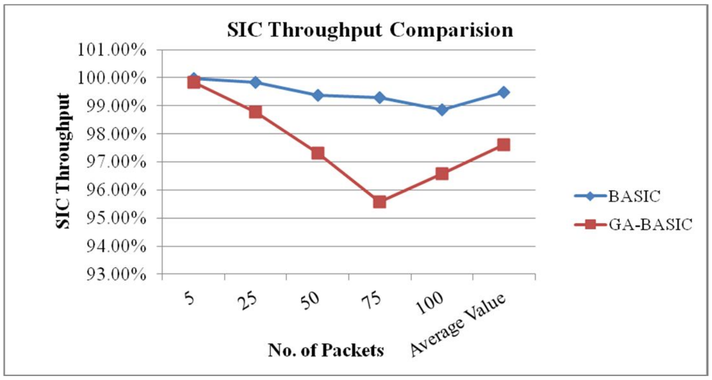

Figure 5 Comparative Analysis of SIC Throughput

Conclusion

In this paper a novel routing protocol is proposed called GA-BASIC, that has high throughput and would dynamically explore SIC opportunities for multi hop wireless networks. A methodology is developed to logically calculate the available bandwidth of a given path with SIC and data is routed on the basis of this calculated SIC. A cluster based network architecture is also designed so that the bandwidth can be estimated by such routing protocol. The route having minimum SIC is selected and data is forwarded along that route. Simulations result shows that the GA-BASIC explores more opportunities, and thus achieves significant throughput gain over other protocols. Based on the proposed approach, it has been formulated the optimization problem mathematically by using genetic algorithm. The division of network into small clusters is based on distance of the nodes among themselves. After distribution of cluster we select the cluster head using genetic algorithm concept which gives optimal number of cluster head and it also reduces the maintenance overhead of routing table as compared to existing protocols in dynamic scenario. Simulation results show that the proposed routing approach and algorithms can significantly improve the throughput and provide a near-optimal solution.

There are many more problems associated with routing that might be subjected to additional research studies like designing of secure routing protocol. The current research works are often extended to design and develop new routing protocols to satisfy the subsequent additional desirable features. A routing protocol should work with robust situations wherever quality is high, nodes are dense, area is massive and therefore the amount of traffic is more. Further analysis in the field like probabilistic route maintenance is desirable to spot the probability of route failure before the occurrences of route failures. A significant issue that should be self-addressed is that the security in ad hoc networks. Applications like Military and Confidential meetings require high degree of security against enemies and active /passive eavesdropping attackers. a new protocol should have authentication headers and necessary key management to distribute keys to the members of ad hoc networks.

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