A Survey of Node Usage Probability in Complex Networks

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Abstract— Communication networks are rapidly becoming the need of time. Internet being the best example to describe. However, traffic congestion is the major cause in degrading the overall performance of the network.Node usage probability is a concept from a complex network perspective for uniformly distributing the traffic load and frequently choosing a node to relay packets in a network. The concept of node usage probability comprises of effective network design strategies, routing algorithms and resource allocation schemes, which helps improve the overall traffic performance. Node usage probability is a metric used wherein the nodes in the network are used efficiently as the problems arise when the nodes are overused or sometimes not used at all inducing congestion in the network thereby hampering the overall performance. The performance of a minimum-node-usage routing algorithm is compared with that based on other routing algorithms, such as shortest path (SP) and minimum degree (MD) routing algorithms, that possess attributes like network topologies and resource allocation schemes that show routing algorithms based on minimizing node usage (MNU) can balance the traffic load effectively also the resource allocation technique based on the node usage probability shows that the technique outperforms the uniform and degree-based allocation schemes. The analysis, as well as the results, gives an idea of what topology to be used, the routing method and the resource allocation scheme, for achieving optimal network performance.

Key words: Shortest path, Minimum degree, Minimum Node Usage

I. INTRODUCTION

Communication networks connect the modern world, Internet being one prominent example of the same. Traffic congestion in many networks has arisen on a larger scale due to the development in the society. Traffic congestion has been studied broadly in the past times in the physics and engineering communities. Communication networks and their topological properties that are described by small-world and scale-free degree distributions, and much work on the same previously carried out has shown that network topology is much relevant to the performance of communication networks, for instance parameters like traffic performance, a vulnerability of attacks, routing effectiveness, and so on.The communication takes place when the digital information is transmitted from a source to a destination that involved routing "packets" from source to destination along a set of intermediate nodes, called a path, which is chosen by the specific choice of routing algorithm. The routing algorithm finds the path to transmit packets from source to destination. The routing algorithm decides the structure of a network with its ultimate traffic performance.Shortest path is one of the strategies that contribute to effective routing in a network. Consider, the heterogeneous network like the Internet, widely used shortest path (SP) routing strategy here gives rise to high traffic loads at some particular hubs in the network, thereby causing congestion of the entire network. To avoid traffic congestion and improve the efficiency at the hubs and reliable flow of information, different routing algorithms were proposed, like the traffic awareness algorithm, the degree-based routing algorithm [1], the local routing algorithm [2], the global dynamic routing strategy [3], and more [4]. Comparing the various kinds of routing strategies, the degree-based routing algorithm [1] is best known for its simplicity and efficiency. The degree based routing strategy aims at finding the path for each pair of the packet with the minimum sum of node's degrees, and the routing algorithm is referred to as minimum degree (MD) routing here. By static topological information, like the traditional SP routing, the MD routing can methodically evade the high degree nodes in the network and efficiently improve the overall performance of the network. For efficient and reliable data transmission [2], the traffic load should be uniformly distributed as possible in the network, and the usual distance traveled by the data should be diminutive. The node usage probability introduced is an effective metric for describing the traffic load distribution and how repeatedly a node is chosen to transmit packets in a network. Established on the concept of node usage probability, design effective strategies are developed to balance the traffic in the network nodes by eluding overuse of some particular nodes. The efficient network design includes minimization of the complete node usage for a given network topology.The Internet autonomous system (AS) level topology has broadly studied and widely used in a variety of exploration.The strategy here involves the use of network build using the Internet interconnection information at AS level from an online database containing 3015 nodes and 5348 links that consider the random graph, the Barabási-Albert (BA) scale-free network [8]and the onion scale-free network[8].Resource allocation based on the node usage probability outperforms the uniform as well as degree-based, and it also allows to identify the optimal operating point in resource allocation.

II. RELATED WORK

The research was carried out on the generic type of communication networks wherein the data in the form of packets was transmitted through connections in the network under SP, MD and combined SP-MD routing algorithms. For instance, the Internet has two type of nodes: routers and hosts. Routers store and forward packets.Hosts are the nodes that can generate and receive packets, and they work as routers as well. In the network density of hosts, ρ is the ratio of the number of hosts to the total number of nodes in the network, which is set to default as $\rho = 0.1$ and hosts are selected randomly in the networks. Packets that are created by the hosts are sent through the links one hop at a time up until they reach the destination. Similarly, each node in the network has its buffer and the size of the buffer for node I being B(i). The data traffic operates in the following ways:1) Packet Generation: New packets are generated at each time step by hosts in the network. Hence, the average number of generated packets by a host node i is λi, which is defined as the creation rate of node i.2) Packet Transmission: The rate packet transmission for a nodeIper step is δ. The first δ packets of each node are forwarded to their destinations, at each time step as per the routing algorithm. 3) Packets Dropped: If the quantity of some packets reaching one node is larger than its buffer that is set to B(i), the remaining packets are dropped. 4) Packets Released: Packets that arrive at their destinations are released from the buffer.

This research was also carried on the generic type of communication networks, Likewise again the form of packets is transmitted through connections in the network under SP and MD routing algorithms. Nodes can work both as hosts and routers to generate and forward packets. Packets that are generated by the nodes are sent through the links one hop at a time while they reach their destinations. Each and every node in the network has a buffer, the size of the buffer for node i isB(i). The data traffic operates as 1) Packet Generation: In the network at each time step,λN new packets are generated with randomly selecting their sources and destinations. Each node at an average generatesλ packets and the total number of nodes in the network is N. 2) Packet Transmission: The transmission rate is δ packets/step for node I. The first δ packets of each node are forwarded at each time step to their destinations by one step according to the routing algorithms. 3) Packets Dropped: If the number of packets arriving at a node is larger than its buffer B(i), the packets are dropped. 4) Packets Released: Packets arrived at their destinations are released from the buffer.Yan et al. [1] proposed a routing strategy that intents were minimizing the sum of degrees of all nodes in the path. Also, the routing algorithm is termed as minimum degree (MD) routing. The algorithm avoids the high degree nodes in the network and efficiently improves the network performance.

The research takes into account the similar hosts and routers theory and works accordingly, the density of hosts is the ratio of the number of hosts to the total number of nodes in the network, the hosts are selected randomly in the network.Packets are generated by the hosts and sent through the communication links selecting the shortest path one hop at a time as they reach their destinations. Each node in the network has a buffer, the size of buffer for node i beingB(i)The operation is as follows:1) Packet Generation: At each time step λ, new packets are generated by hosts. The average number of generated packets by a host is defined as the generation rate of a node. 2) Packet Transmission: The transmission rate for node per step is. At each time step, the first packets of a node are forwarded toward their destinations by one step according to the routing algorithm. 3) Packets Dropped: If the total number of packets reaching one node is larger than its bufferB(i)the outstanding packets are destroyed or dropped. 4) Packets Released: Packets already arrived at their destinations released from the buffer. Both SP and MD routing algorithms are considered while the network was functioning λN.

The research comprises of all the nodes where they either work as hosts or routers to generate and or forward packets. Packets that are generated are sent through the path links one hop at a time as they reach their destinations. Also, each and every node in the network has an infinite buffer to store the packets waiting for processing.The data traffic works as follows.1) Packet generation: New packets are generated at each time step.The average packet generated by each node isλ, and the destination is randomly chosen, when the packet is generated from the rest of the network.2) Packet Transmission: NodeI has a transmission capacity as is R(i). Packets that arrive at their destinations are released from the buffer. The first R(i)packets of node i are forwarded to their destinations at each time step, by one step as per the routing algorithms. The constraints such as fixed network topology, node usage probability, and traffic load distribution, are obtained by the routing algorithm. The aim is to find the optimal formation of routing links to make Cmax as small as possible. Although, irregular networks such as the scale-free network,finding the peak pattern of paths by assessing all possible paths among each pair of nodes is infeasible. The difficult task of finding all possible paths between two nodes in the network was verified to be NP-hard [5]. In effective routing [6], the performance can be enhanced by decreasing the node usage probability and minimizing the average distance. The minimum node usage (MNU) routing has been proposed and demonstrated for its efficiency. The simulated algorithm, SA[7] is taken into practice,to find a near-optimal solution as it is essentially an optimized MNU algorithm.

In this paper, all nodes can work as both hosts and routers to generate and forward packets. Packets are generated by the nodes and transferred through the links, one hop at a time as they reach their destinations. Each node in the network has a buffer and the buffer size for node I being B(i). Then, the data traffic operates as follows: 1) Packet Generation: At each time step, λNnew packets are generated with randomly selected sources and destinations. The average number of generated packets by each node is λ, and N is total node number of the networks. 2) Packet Transmission: The transmission rate for node I am δ packets/step. At each time step, the first δ packets of each node are forwarded to their destinations by one step according to the routing algorithms.3) Packets Dropped: If the total number of packets reaching one node is larger than its buffer B(i), the outstanding packets are dropped or destroyed.4) Packets Released: Packets already arrived at their destinations are released from the buffer.

The strategy where all nodes can work as either hosts or routers to generate or forward packets is considered here. Packets generated by the nodes are sent through the links one hop at a time until they reach the destinations.Each node in the network has a buffer, the buffer size for the node beingB(i). The data traffic operates as follows:1) Packet Generation: At each time step, new packets are generated randomly with selected sources and destinations. Assuming the average number of generated packets in time step by each node is, and is a total number of nodes of the networks. The number of packets generated in each time step is thus equal to.2) Packet Transmission: The transmission capacity for a node isR(i). At each time step, the first packets of a node are forwarded to their destinations by one step according to the routing algorithms. 3) Packets Dropped: If the total number of packets reaching one node is larger than its buffer, the outstanding packets are dropped or destroyed.4) Packets Released: Packets already arrived at their destinations are released from the buffer.

III. TABLE OF COMPARISON

Title	Author	Mechanism	Advantage	Limitations
1] Complex Network approach to communication Network performance analysis	Jiajing Wu, Chi K. Tse, Francis C.M. Lau, and Ivan W.H. Ho	The concept lies in the removal of a certain number of high degree nodes in a scale-free network along with shortest path routing may help minimize the drop rate.	The overall network performance can be improved when the high-degree nodes are used exclusively as a specific group of nodes.	The random attack causes the nodes to be removed randomly from the network. The packets that begin or end at a removed nodes are dropped
2] An Adaptive Routing Algorithm for Load Balancing In Communication Networks	Jiajing Wu, Chi K. Tse, Francis C. M. Lau, and Ivan W. H. Ho	An adaptive routing algorithm is proposed considering both the network structure And the dynamic traffic information. Also, it is compared with shortest path (SP) and minimum degree (MD) routing algorithms Regarding packet drop rate and packet transmission time.	The proposed routing algorithm can effectively balance the traffic in the network and improve the overall network performance.	In SP routing, nodes with a higher degree are selected as routers with a high probability and are more vulnerable to congestion.
3] Analysis of Communication Network Performance From a Complex Network Perspective	Jiajing Wu, Chi K. Tse, Fellow, IEEE, FrancisC.M. Lau, Senior Member, IEEE, and Ivan W. H. Ho	The node usage probability an effective metric for describing the traffic load distribution is proposed and how often a node is chosen to transmit packets in a network, metric, which depends on the network topology and routing algorithm.	The degree-based node usage probability-based resource allocation can enhance the network performance. The node usage probability-based allocation gives the best performance.	Using BA scale-free network, the higher degree nodes have a much higher probability to be chosen as a router, making them vulnerable to congestion and restricting the throughput of the network
4]Optimizing Performance of Communication Networks: An Application of Network Science	Jiajing Wu, Chi K. Tse, Fellow, IEEE, and Francis C. M. Lau, Senior Member, IEEE	Simulated annealing algorithm has been proposed to find a near-optimal solution for minimum node usage.	SA algorithm performs better than other three algorithms regarding critical generation rate, average transmission time.	Since the traffic the load is more uniformly distributed in the network; nodes become congested after the network enters a congestion state, causing a rapid decrease in the overall throughput.
5] Effective Routing Algorithms Based on Node Usage Probability from a Complex Network Perspective	Jiajing Wu, Chi K. Tse, and Francis C. M. Lau	By node usage probability, an effective routing method is proposed to balance traffic and avoid overuse of some nodes	Proposed routing effectively improve the overall network performance.	In a low traffic intensity, the proposed routing has the same transmission time as SP routing.

Table 1. Table of Comparison

IV. PROPOSED STRATEGY

The proposed strategy comprises of the system that undertakes node usage probability as an important metric from the performance perspective and also the algorithm that for the path chosen along the network.

Established on the concept of node usage probability, design effective strategies for the network, containing routing algorithms and resource allocation patterns, are used to improve the overall traffic performance.

The shortest path (SP) routing is a widely used routing algorithm in communication networks. The shortest path comprises a path with a minimum number of hops from source to the destination. It is a routing strategy used in many real-world communication networks due to its simplicity and efficiency.

Yan et al. [1] proposed a routing algorithm that aims to minimize the sum of the degrees of all nodes in the path, also referred to as minimum degree (MD) routing. The algorithm can thoroughly avoid the high degree nodes in the network and efficiently improve the overall network performance.

The resource allocation is also a significant factor that affects the overall network throughput. For example the Internet AS-level. The results of SP, MD, and MNU routing algorithms are studied on the four networks along with uniformly distributed resource. Two kinds of resources, namely, buffer size and transmission capacity are considered. The transmission capacity of each node is set to 5 packets and the buffer size of each node as 500 packets.

The four different networks taken into consideration are Onion scale free, Barabasi-Albert(BA), ER random and the Internet and the routing algorithms compared are Shortest Path, Minimum Degree, Minimum Node Usage.

Since the node usage probability is an effective and valuable metric from a complex network perspective, an algorithm can be derived to achieve optimum network performance also which would prove efficient and effective for the complex networks

V. CONCLUSION

Node usage probability must be the basic concern in any network design, for efficient data transmission, the traffic load must be distributed as evenly as possible in the network and the average distance for network must be as short as possible.The node usage probability is valuable metric for characterizing the traffic load distribution and how often a node is chosen to transmit packets in a network. Therefore, the routing based on minimizing node usage would direct to balance traffic loads in the network also improve the overall network performance.

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