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Throughput Maximization Using Portfolio Selection and Jamming-Aware Routing Algorithm

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Abstract

In networking, data can be sent from source to destination through multiple available paths. However, there are problems like jamming that prevent data from reaching the correct destination. This Jamming aware traffic allocation can solve this problem. This paper presents a solution for jamming problem in network with multi-path routing. The solution is based on the jamming statistics at each and every node in the network. The allocation of traffic here is known as jamming-aware traffic allocation. In the process of traffic allocation portfolio selection theory is used which is meant for balancing data throughput. The proposed solution is capable of estimating the traffic jamming probabilities and take decisions with regard to traffic allocation. A custom simulator application is built to demonstrate the efficiency of the proposed system. The empirical results revealed that the system is capable of allocating traffic based on the jamming awareness it has.

Keywords–*Traffic allocation, jamming, portfolio selection, multi-path routing.*

1. Introduction

In Wireless Mesh Networks jamming of traffic between nodes is a problem to be solved. The jamming might be the result of an attack known as "Jamming Attack". The Jamming attack causes the data transmission between the source and destination to be stopped. Jamming can also occur in networks like UAN (Underwater Acoustic Network). The jamming attack has its effect at physical layer of network and spread through the protocol stack. This causes the denial of service attacks [1] that prevent end to end communication. To overcome such drawbacks, solutions like forcing jammers to extend a resource, beam forming and spread-spectrum are used. However, all are meant for reaching the same goal. Cross layer protocol information can be incorporated into jamming attacks then such jammers are known as intelligent jammers. It reduces the layer resource expenditure to a greater extent. This is achieved by using link layer and MAC implementations provided in [2], [3], [4] and [5].
Into higher layer level protocols more sophisticated anti-jamming methods are to be incorporated. Such examples include routing around jammed regions of network and surfing [6]. Diversity is the common feature exhibited by most of the anti-jamming techniques. The protocols pertaining to anti-jamming make use of multiple pre-routing paths, various MAC channels and multiple frequency bands. The effects of such attacks are overcome by making the jammer to require to act on many sources concurrently. In this paper, the anti-jamming diversity based multiple routing paths. The variants of such routing protocol are AODV (Ad-Hoc On-Demand Distance Vector), DSR (Dynamic Source Routing) [7] and MP-MPDSR [8] protocols. Several DSR routing paths can be requested by each source node to the destination node for simultaneous use. In order to make it effective, the source nodes that send traffic are expected to allocate traffic intelligently from the available paths keeping jamming probabilities in mind.

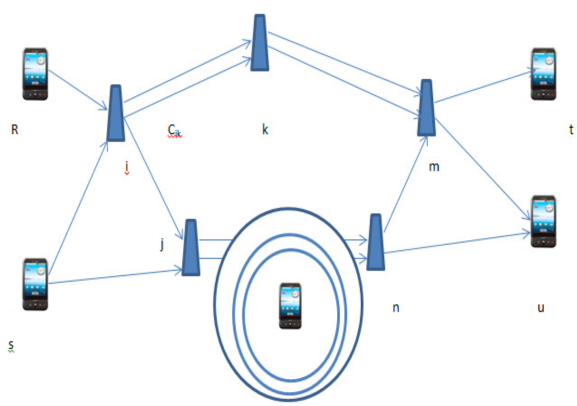

Fig. 1 –Network in the presence of jammer

For the purpose of characterizing the effect of jamming locally, each source node should gather data of jamming at various parts of the network. Actuallythe jamming at a network node depends on many parameters which are not known. The parameters may include relative location of jammers, strategy adapted by attackers and so on. This is with regard to the transmitter-receiver pair. The process of finding the probability of jamming and its characteristics, impact of it on the network is very tedious task. This is because the strategies used by attackers may change from time to time. In order to model situations such as dynamic and non-deterministic, the packet error rate is computed at each node randomly. As jamming parameters are uncertain, this results in randomness of packet error rate. The effect of jamming and the throughput achieved by sender and receiver pairs are non-deterministic as they are most probabilistic in nature at each node. Hence to model such characteristics in network, a stochastic framework has to be used. In this paper, we explore the ability of nodes in the network to characterize the jamming and impact in the network. The contributions of this paper include formulating a problem in which traffic is allocated across the paths in presence of jammers. The optimization problem is considerd to be the lossy network flow optimization problem. This problem is them mapped to the theory of portfolio selection [9], [10]. A distributed algorithm which runs at each and every node is developed. This algorithm is based on NUM [11]. Methods are devised for the individual nodes to characterize the impact of jamming. The theory of portfolio selection is demonstrated.

2. Proposed System Model

A wireless network of interest is considered. It is assumed that all communications are unicast. Each packet transmitted is intended to send to a particular destination node. It has maximum data rate that can be achieved which is also known as constant rate. The measurement is units per second. It is also assumed that multiple routing paths are generated by each source node. Here the process of route request is similar toDSR [12] or AODV [7]. The paths in the routing process should not be disjoint as in MP-DSR [8]. It is also assumed that the source nodes that send packets to destination node have no knowledge apriori about possible jamming attacks and the location of jammers and their number are also unknown.

For this reason the proposed model characterizes the impact of jamming in terms of packet delivery rate. The source nodes in the network relay on required information for traffic allocation intelligently. That is why the nodes provide information to source node each time the network structure is changed or when a routing path is requested or existing path gets updated. From the route reply of other nodes, each source node is equipped with required information for effective traffic allocation.

3. Jamming Impact Characterization

For the nodes in the network to estimate and characterize the impact of jamming the proposed techniques are described here. Hoever, these are the local estimates and need to be updated as and when required. The jammer mobility and its effect is described with the help of the network which shows a source node with three paths to the destination node as shown in fig. 2.

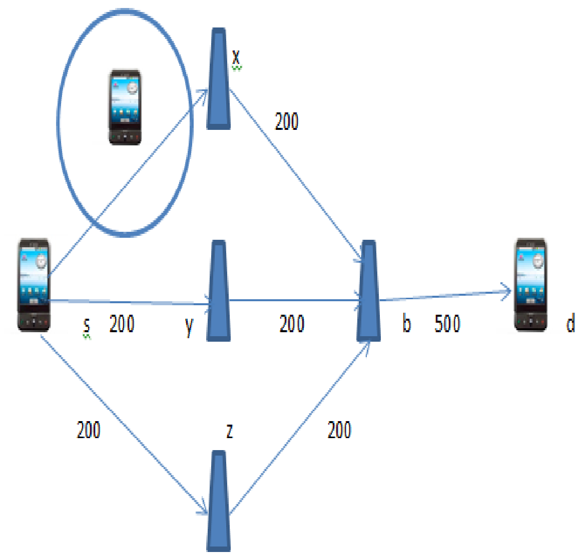

Fig. 2 –Single source network with multiple paths

As can be seen in fig. 2, there are six nodes in the network. The source node is labeled “s” which has three paths to send packets to destination node which is represented by “d”. The numeric labels on each edge indicate link capacity. The value is nothing but number of packets. The source is assumed to sent packets at rate 300. It is so when jammers do not exist in the network. Equal traffic allocation is made to all paths generally. However, when source node is aware of jamming on a particular path, it will reduce the packet allocation to that path or take such decision based on the statistics pertaining to jamming. Estimation of packet success rate locally is done analytically. It involves consideration of signal power of node, jammer’s signal power, the distance between the source node and jammer, wireless medium’s path loss behavior. However, in the real world the location of jammers is not known. For this reason the usage of that kind of analytical model is not practical. As there is uncertaininty pertaining to impact of jamming, we use the packet success rate as random process. Each node is supposed to estimate the packet success rate, variance parameter in order to characterize the process variability and uncertainty. Recursive update mechanism is proposed which updates information at each node as and when required. Packet delivery ratio is used to compute packet success rate. The model used to update this is EWMA (Exponential Weighted Moving Average) [13]. It is also used to update variance. It is a sequential estimation process and that includes RTT (Round Trip Time).

4. Jamming- Aware Traffic Allocation

This section provides information about how the source node in the network can allocate traffic to all the paths that lead to destination in the presence of a jammer. The constraints used in the process include reduction of traffic flow, link capacity constraints, and source data rate constraints. When there is jammer in the network, the packet receiving rate gets reduced at destination node due to the loss of packets. On each path the capacity constraint is applied. Residual packet success rate is introduced to compensate randomness with respect to capacity constraint [6]. Portfolio selection theory can also be used to allocate traffic optimally. The portfolio selection theory adapted here is taken from [9] and [10]. According to the theory the following table compares portfolio selection of a real world sector and also network.

Portfolio Selection	Traffic Allocation
Funds to be invested	Source data rate
Financial assets	Routing paths
Expected Asset return	Expected Packet success rate
Investment portfolio	Traffic allocation
Portfolio return	Mean throughput
Portfolio risk	Estimation variance

Table 1 –Traffic Allocation and Portfolio Selection Comparison

As can be seen in table 1, the traffic allocation considers source data rate, routing paths, expected packet success rate, traffic allocation, mean throughput and estimation variance. The expected performance is computed using return and risk. The return represents the growth of assets. The risk is the variance of the asset due to uncertain growth. The analogy compares both portfolio selection theory and also traffic allocation in the proposed system.

5. Evaluation of Empirical Results

Custom simulator is built to make experiments. Various techniques pertaining to optimal traffic allocation and estimating local jamming impact are evaluated. Several methods of traffic allocation of interest are compared under given network and jamming models. The following cases are defined here. The first case is to ignore jamming. This is the case in which the presence of jamming is ignored. In case 2, maximum throughput is considered. Jamming aware optimization is expected to be carried out here for maximum throughput. In case 3, considers uncertaintyparameters that are used to balance mean throughput. The fourth case is Oracle model. It is used to ensure continuous optimization.

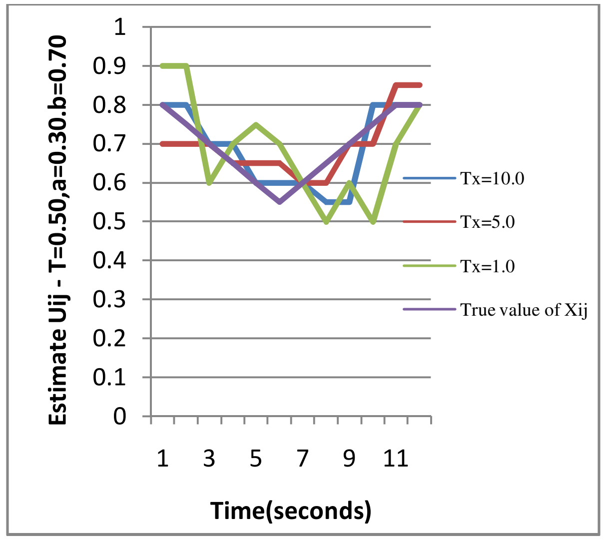

Fig. 3–Packet success rate with estimate

As can be seen in fig. 3, the horizontal axis represents time in seconds while the vertical axis shows the estimate of success rate.

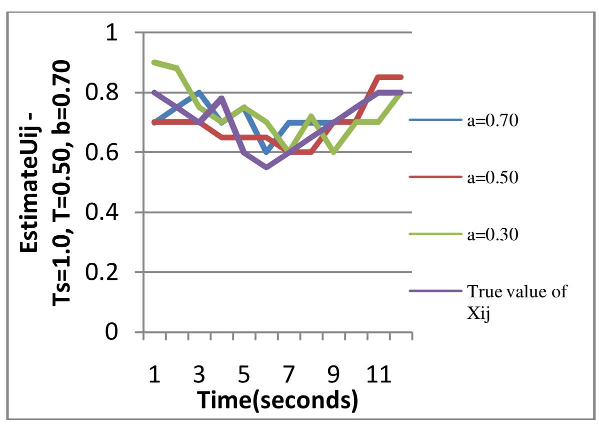

Fig. 4 – the EWMA coefficients

As can be seen in fig. 4, the horizontal axis represents time in seconds while the vertical axis shows the estimate of success rate.

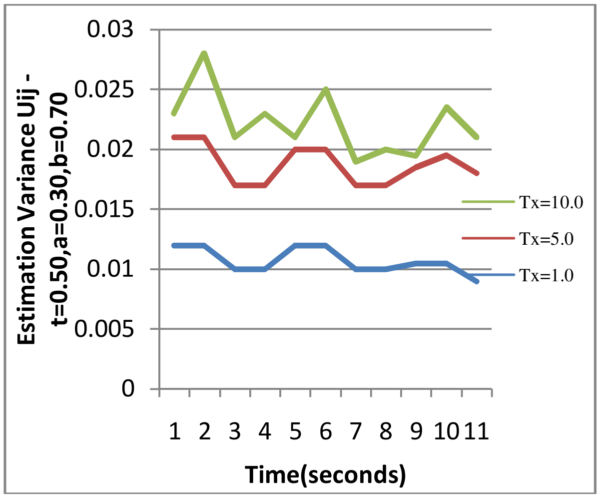

Fig. 5 – Packet success rate with variance

As can be seen in fig. 5, the horizontal axis represents time in seconds while the vertical axis shows the variance of success rate.

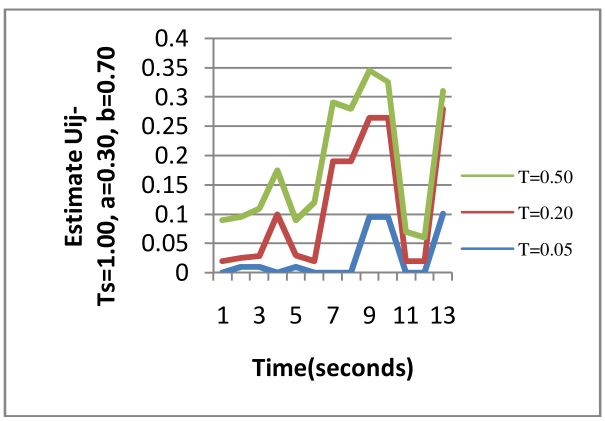

Fig. 6 – The update period

As can be seen in fig. 6, the horizontal axis represents time in seconds while the vertical axis shows the estimate of update period.

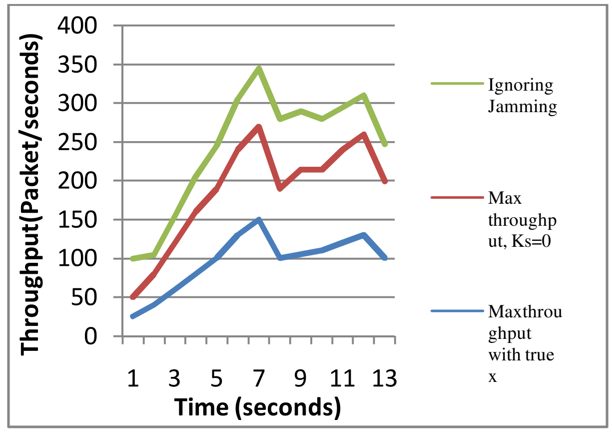

Fig. 7 – the EWMA coefficients

As can be seen in fig. 7, the horizontal axis represents time in seconds while the vertical axis shows throughput or packets per second.

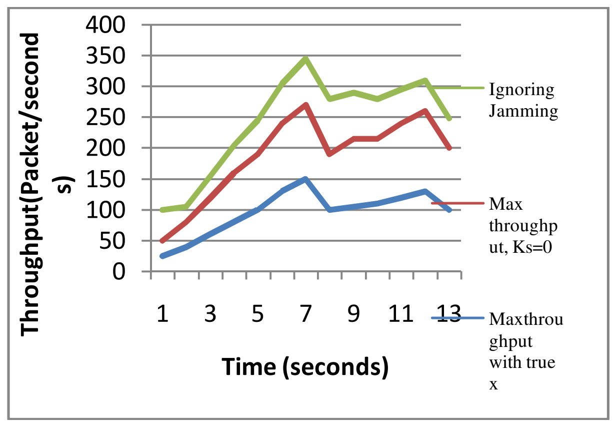

Fig. 8–Simulated throughput

As can be seen in fig. 8, the horizontal axis represents time in seconds while the vertical axis shows throughput.

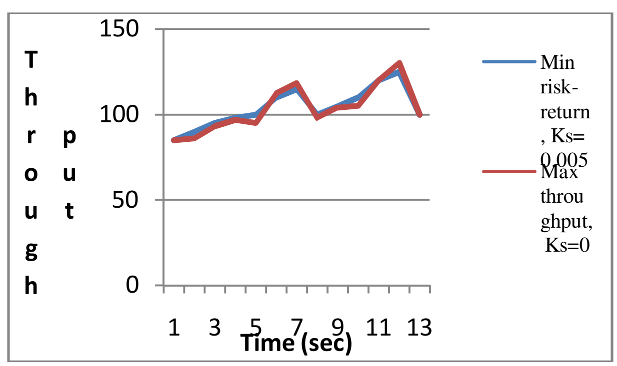

Fig. 9– Simulated throughput

As can be seen in fig. 5 (d), the horizontal axis represents time in seconds while the vertical axis shows throughput.

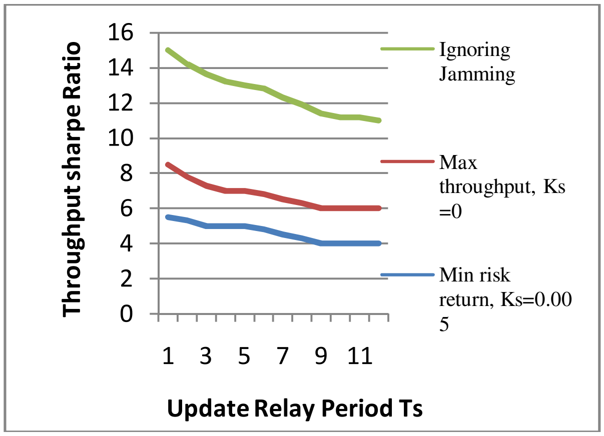

Fig. 10 –Updated delay and throughput

As can be seen in fig. 6 (b), the horizontal axis represents time in seconds while the vertical axis shows throughput.

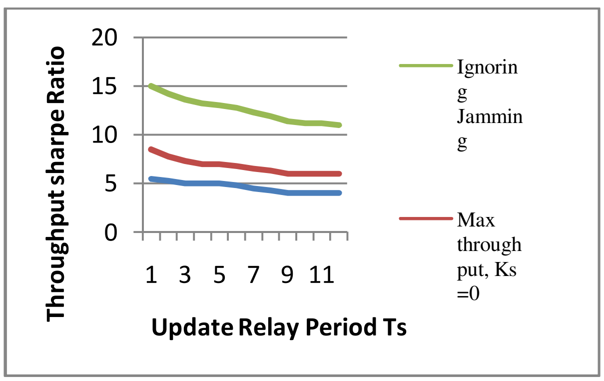

Fig. 11 – Updated delay and throughput

As can be seen in fig. 6 (d), the horizontal axis represents time in seconds while the vertical axis shows throughput.

6. Conclusion

Routing algorithms take care of routing of data from sender to destination. In the presence of jammers, multi-path routing algorithmshave to perform jamming – aware routing. Towards this end this paper proposed an approach based on the empirical jamming statistics to allocate traffic in multi-path source routing to avoid jamming problems. This can address the problem of jamming. At each node the algorithm characterize the local impact of jamming attack probabilistically. The empirical jamming statistics are incorporated into the routing algorithm. We understood that the multi-path source routing in presence of jammers is the optimization problem. Hence the algorithm is developed based on the concept of Network Utility Maximization (NUM). We also built a custom simulator which demonstrates the efficiency of the proposed algorithm. The empirical results revealed that the algorithm is jamming-aware and allocate traffic appropriately.

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