Global Journal of Computer Science and Technology
Network, Web & Security
Volume 12 Issue 14 Version 1.0 Year 2012
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 0975-4172 & Print ISSN: 0975-4350

Portfolio Selection in Multipath Routing for Traffic Allocation

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GJCST-E Classification : C.2.2

PORTFOLIO SELECTION IN MULTIPATH ROUTING FOR TRAFFIC ALLOCATION

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M. Karunakar Reddy [α] & S. Nageswara Rao [σ]

Abstract - Multiple-path source routing protocols allow a data source node to distribute the total traffic among available paths. In this article, we consider the problem of jamming-aware source routing in which the source node performs traffic allocation based on empirical jamming statistics at individual network nodes. We formulate this traffic allocation as a lossy network flow optimization problem using portfolio selection theory from financial statistics. We show that in multi-source networks, this centralized optimization problem can be solved using a distributed algorithm based on decomposition in network utility maximization (NUM). We demonstrate the network's ability to estimate the impact of jamming and incorporate these estimates into the traffic allocation problem. Finally, we simulate the achievable throughput using our proposed traffic allocation method in several scenarios.

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I. Introduction

Jamming point-to-point transmissions in a wireless mesh network [1] or underwater acoustic network [2] can have debilitating effects on data transport through the network. The effects of jamming at the physical layer resonate through the protocol stack, providing an effective denial-of-service (DoS) attack [3] on end-to-end data communication. The simplest methods to defend a network against jamming attacks comprise physical layer solutions such as spread-spectrum or beam forming, forcing the jammers to expend a greater resource to reach the same goal. However, recent work has demonstrated that intelligent jammers can incorporate cross layer protocol information into jamming attacks, reducing resource expenditure by several orders of magnitude by targeting certain link layer and MAC implementations [4]–[6] as well as link layer error detection and correction protocols. The majority of ant jamming techniques make use of diversity. For example, ant jamming protocols may employ multiple frequency bands, different MAC channels, or multiple routing paths. Such diversity techniques help to curb the effects of the jamming attack by requiring the jammer to act on multiple resources simultaneously. In this paper, we consider the ant jamming diversity based on the use of multiple routing paths. Using multiple-path variants of source routing protocols such as Dynamic Source Routing (DSR) or Ad Hoc On-Demand Distance Vector (AODV), or example the MP-DSR protocol, each source node can request several routing paths to the destination node for concurrent use. To make effective use of this routing diversity, however, each source node must be able to make an intelligent allocation of traffic across the available paths while considering the potential effect of jamming on the resulting data throughput. In order to characterize the effect of jamming on throughput, each source must collect information on the impact of the jamming attack in various parts of the network.

However, the extent of jamming at each network node depends on a number of unknown parameters, including the strategy used by the individual jammers and the relative location of the jammers with respect to each transmitter–receiver pair. Hence, the impact of jamming is probabilistic from the perspective of the network, and the characterization of the jamming impact is further complicated by the fact that the jammers' strategies may be dynamic and the jammers themselves may be mobile.2 In order to capture the nondeterministic and dynamic effects of the jamming attack, we model the packet error rate at each network node as a random process. At a given time, the randomness in the packet error rate is due to the uncertainty in the jamming parameters, while the time variability in the packet error rate is due to the jamming dynamics and mobility. Hence, more sophisticated anti-jamming methods and defensive measures must be incorporated into higher-layer protocols, for example channel surfing [8] or routing around jammed regions of the network [6].

a) My Contributions

- We formulate the problem of allocating traffic across multiple routing paths in the presence of jamming as a lossy network flow optimization problem.
- We map the optimization problem to that of asset allocation using portfolio selection theory. We formulate the centralized traffic allocation problem for multiple source nodes as a convex optimization problem.
- We show that the multi-source multiple-path optimal traffic allocation can be computed at the source nodes using a distributed algorithm based on decomposition in network utility maximization (NUM).

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- We propose methods which allow individual network nodes to locally characterize the jamming impact and aggregate this information for the source nodes.
- We demonstrate that the use of portfolio selection theory allows the data sources to balance the expected data throughput with the uncertainty in achievable traffic rates.

II. Background

a) Characterizing the Impact of Jamming

In this Module, the network nodes to estimate and characterize the impact of jamming and for a source node to incorporate these estimates into its traffic allocation. In order for a source node s to incorporate the jamming impact in the traffic allocation problem, the effect of jamming on transmissions over each link must be estimated. However, to capture the jammer mobility and the dynamic effects of the jamming attack, the local estimates need to be continually updated.

b) Effect of Jammer Mobility on Network

The capacity indicating the link maximum number of packets per second (pkt/s) eg: 200 pkts/s which can be transported over the wireless link. Whenever the source is generating data at a rate of 300 pkts/s to be transmitted at the time jamming to be occurring. Then the throughput rate to be less. If the source node becomes aware of this effect the allocation of traffic can be changed to 150 pkts/s on each of paths thus recovers the jamming path.

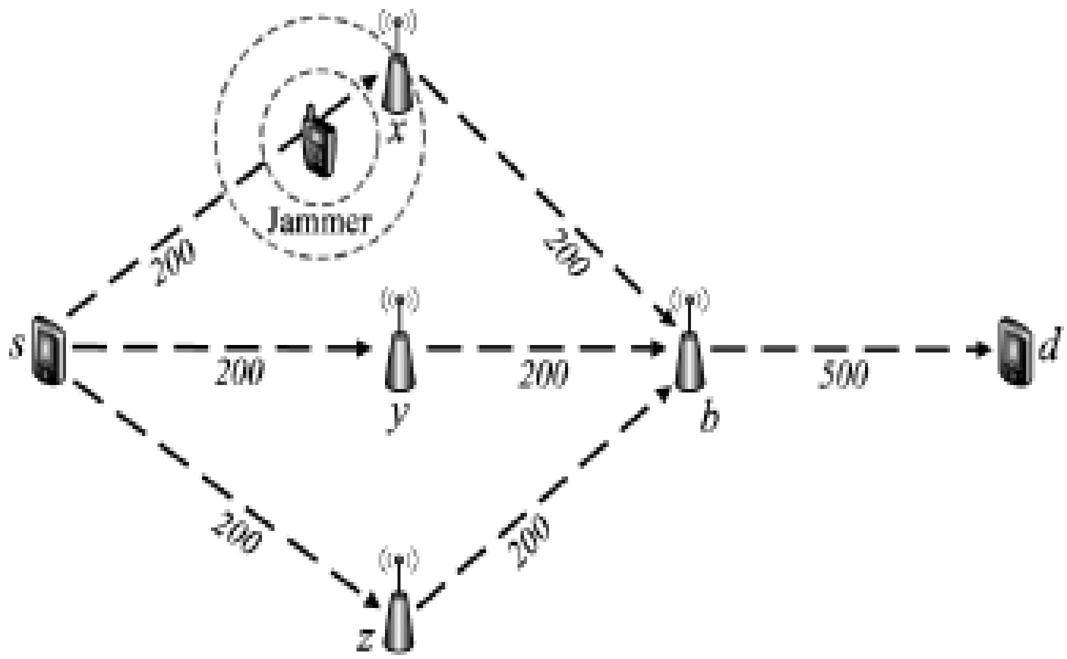


Fig.1 : An example network that illustrates a single-source network with three routing paths.

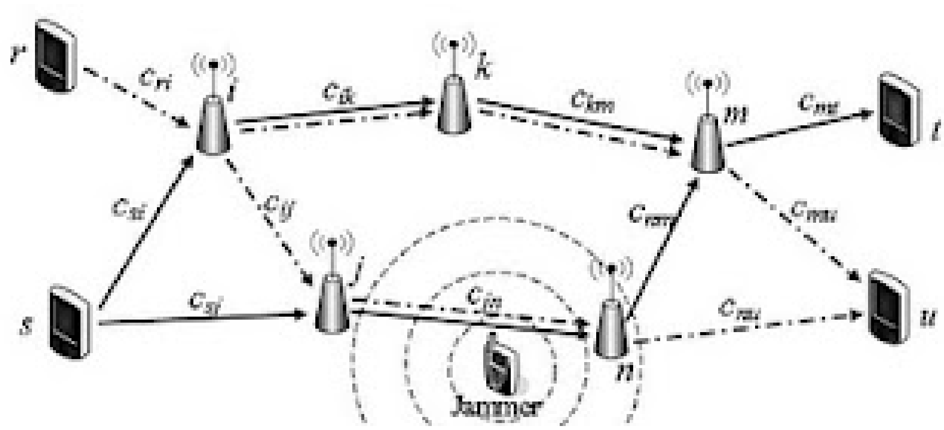


Fig. 2 : An example network with sources S = {r, s} is illustrated. Each unicast link (i, j) ! E is labeled with the corresponding link capacity

c) Estimating End-to-End Packet Success Rates

The packet success rate estimates for the links in a routing path, the source needs to estimate the effective end-to-end packet success rate to determine the optimal traffic allocation. Assuming the total time required to transport packets from each source s to the corresponding destination is negligible compared to the update relay period

d) Computational Complexity

We note that both the centralized optimization problem in and the local optimization step in the distributed algorithm are quadratic programming optimization problems with linear constraints . The computational time required for solving these problems using numerical methods for quadratic programming is a polynomial function of the number of optimization variables and the number of constraints.

e) Optimal Jamming-Aware Traffic Allocation

An optimization framework for jamming-aware traffic allocation to multiple routing paths for each source node. We develop a set of constraints imposed on traffic allocation solutions and then formulate a utility function for optimal traffic allocation by mapping the problem to that of portfolio selection in finance. In order to define a set of constraints for the multiple-path traffic allocation problem, we must consider the source data rate constraints, the link capacity constraints, and the reduction of traffic flow due to jamming at intermediate nodes. Due to jamming at nodes along the path, the traffic rate is potentially reduced at each receiving node as packets are lost.

In Markowitz's portfolio selection theory an investor is interested in allocating funds to a set of financial assets that have uncertain future performance. The expected performance of each investment at the time of the initial allocation is expressed in terms of return and risk. The return on the asset corresponds to the value of the asset and measures the growth of the investment. The risk of the asset corresponds to the variance in the value of the asset and measures the degree of variation or uncertainty in the investment's growth. We describe the desired analogy by mapping this allocation of funds to financial assets to the allocation of traffic to routing paths. We relate the expected investment return on the financial portfolio to the estimated end-to-end success rates and the investment risk of the portfolio to the estimated success rate covariance matrix .We note that the correlation between related assets in the financial portfolio corresponds to the correlation.

Packet delivery ratio: The packet delivery ratio in this simulation is defined as the ratio between the number of packets sent by constant bit rate sources (CBR,"application layer") and the number of received packets by the CBR sink at destination.

Routing Overhead: It is the number of packet generated by routing protocol during the simulation.

Average end-to-end delay of data packets: There are possible delays caused by buffering during route discovery latency, queuing at the interface queue, retransmission delays at the MAC, and propagation and transfer times. Once the time difference between every CBR packet sent and received was recorded, dividing the total time difference over the total number of CBR packets received gave the average end-to-end delay for the received packets. This metric describes the packet delivery time: the lower the end-to-end delay the better the application performance.

Distributed Jamming-Aware Traffic Allocation

Initialize $n = 1$ with initial link prices $\boldsymbol{\lambda}_1$.

1. Each source s independently computes
$$\phi^*_{s,n} = \underset{\phi_s \in \Phi_s}{\arg\max} \left(\gamma_s^T - \boldsymbol{\lambda}_n^T \mathbf{W}_s\right)\phi_s - k_s \phi_s^T \Omega_s \phi_s.$$
2. Sources exchange the link usage vectors $u_{s,n} = \mathbf{W}_s \phi^*_{s,n}$.
3. Each source locally updates link prices as
$$\boldsymbol{\lambda}_{n+1} = \left(\boldsymbol{\lambda}_n - a\left(c - \sum_{s \in S} u_{s,n}\right)\right)^+.$$
4. If $\|\phi^*_{s,n} - \phi^*_{s,n-1}\| > \epsilon$ for any s, increment n and go to step 1.

f) Traffic Allocation Constraints

In order to define a set of constraints for the multiple-path traffic allocation problem, we must consider the source data rate constraints, the link capacity constraints, and the reduction of traffic flow due to jamming at intermediate nodes. The traffic rate allocation vector "s is trivially constrained to the nonnegative orthant, i.e. "s * 0, as traffic rates are non-negative.

III. Case Study

a) Routing

Routing is the process of selecting paths in a network along which to send network traffic. Routing is performed for many kinds of networks, including the telephone network (Circuit switching), electronic data networks (such as the Internet), and transportation networks. This article is concerned primarily with routing in electronic data networks using packet switching technology.

b) Routing protocol

A routing protocol is a protocol that specifies how routers communicate with each other, disseminating information that enables them to select routes between any two nodes on a computer network, the choice of the route being done by routing algorithms. Each router has *a priori* knowledge only of networks attached to it directly. A routing protocol shares this information first among immediate neighbours, and then throughout the network. This way, routers gain knowledge of the topology of the network.

c) Multiple path Routing

Multipath routing is the routing technique of using multiple alternative paths through a network, which can yield a variety of benefits such as fault tolerance, increased bandwidth, or improved security. The multiple paths computed might be overlapped, edge-disjointed or node-disjointed with each other.

IV. Performance Evaluation

In this section, we simulate various aspects of the proposed techniques for estimation of jamming impact and jamming aware traffic allocation. We first describe the simulation setup, including descriptions of the assumed models for routing path construction, jammer mobility, packet success rates, and estimate updates. We then simulate the process of computing the estimation statistics µij (t) and !2 ij (t) for a single link (i, j). Next, we illustrate the effects of the estimation process on the throughput optimization, both in terms of optimization objective functions and the resulting simulated throughput.

Distributed Formulation Algorithm:

Input: Load

Output: Allocates the load in different number of paths

Step1: starts the packets allocation

Step2: select multiple source and multiple destination

Step3: forward the feedback from first route to next route

Sep4: packets allocation in different number of routes till gets the optimal solution

Step5: All the routes are distributes successfully using parallel paths communication

V. Simulation setup

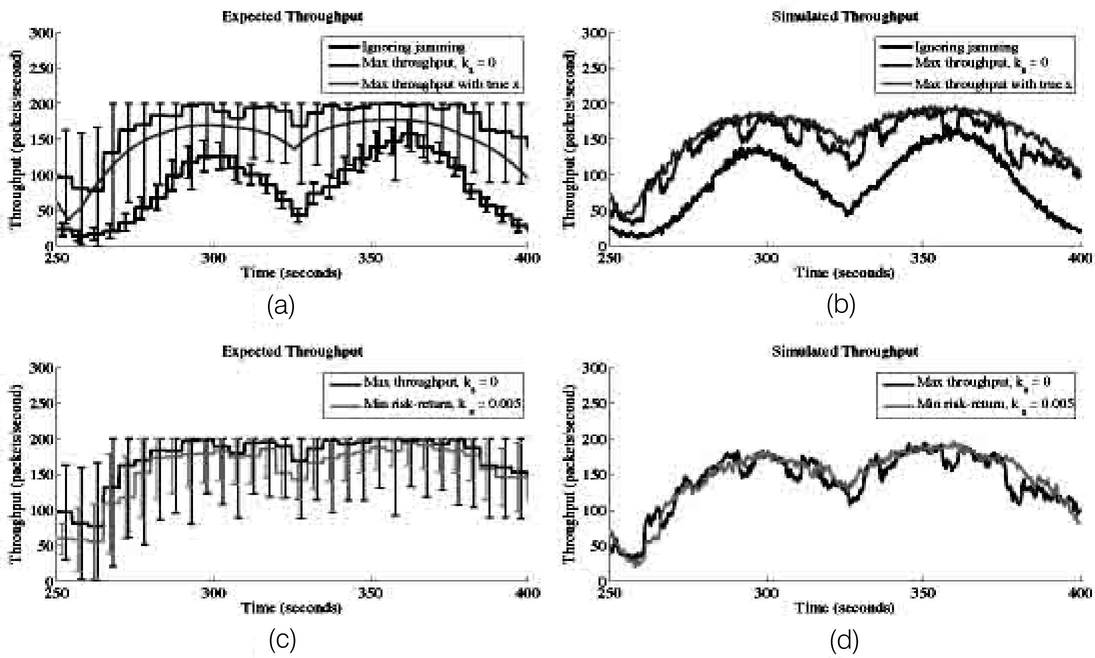
The simulation results presented herein are obtained using the following simulation setup. A network of nodes is deployed randomly over an area, and links are formed between pairs of nodes within a fixed communication range. The set S of source nodes is chosen randomly, and the destination node ds corresponding to each source s! S is randomly chosen from within the connected component containing s.

a) Simulation of Estimation Process

We first simulate the process of computing the estimate µij(t) and the variance !2 ij (t) over a single link (i, j). Figure 4 shows the true packet success rate xij (t) with the estimate µij(t) and the estimation variance !2 ij (t) for various parameter values. By inspection of below Figure , we see that a shorter update relay period Ts and a longer update period T yield a more consistent estimate µij (t) with less variation around the true value of xij (t).

b) Simulation of Parameter Dependence

We next evaluate the effect of varying network and protocol parameters in order to observe the performance trends using the jamming-aware traffic allocation formulation. In particular, we are interested in the effect of the update relay period Ts and the maximum number of routing paths |Ps| on the performance of the flow allocation algorithm.



VI. Conclusion and Future work

We studied the problem of traffic allocation in multiple-path routing algorithms in the presence of jammers whose effect can only be characterized statistically. We have presented methods for each network node to probabilistically characterize the local impact of a dynamic jamming attack and for data sources to incorporate this information into the routing algorithm. We formulated multiple-path traffic allocation in multi-source networks as a lossy network flow optimization problem using an objective function based on portfolio selection theory from finance. We showed that this centralized optimization problem can be solved using a distributed algorithm based on decomposition in network utility maximization (NUM). We presented simulation results to illustrate the impact of jamming dynamics and mobility on network throughput and to demonstrate the efficacy of our traffic allocation algorithm. We have thus shown that multiple path source routing algorithms can optimize the throughput performance by effectively incorporating the empirical jamming impact into the allocation of traffic to the set of paths. We propose a scheme based on multiple routing paths. The wireless network of interest can be represented by a directed graph. The solution is when a source node S want to send data to a target node T, it finds all the paths to route the packet from S to T. The traffic to be sent from S to T is split and sent across multiple paths. Say there is 100 packets to be sent, how many packets to sent in each routing path is to be decided. The logic of how to split the traffic across multiple paths takes into consideration the expected jamming in each path. The algorithm to solve is called as Optimal Jamming aware traffic allocation.

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