Zone-based Multi-path Routing for Congestion Control in the Internet

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Abstract

This paper focuses on developing multi-path routing mechanisms to achieve congestion control in the Internet. Specifically, our goal is to make use of the availability of multiple routes between a pair of zones. We name our approach Zone-based Multi-path Routing (ZMR). By zone we mean, a single or a set of neighboring autonomous systems (ASes). In traditional approaches to multi-path routing, messages are routed on the node-to-node basis, i.e. micro level. Information about alternate paths to be used if the current single path in use breaks have to be kept, and their measurements of traffic are micro-level and static, where request messages are flooded to obtain traffic information. We newly discuss a macro level routing where routes are decided based on the zone concept. Here, even if network environment is changed, a route can be easy decided.

Keywords: Routing, Multi-path, Disjoint Path, Congestion Control, Autonomous Systems, and Zone.

1. Introduction

As the Internet continues growing and new technologies emerge to meet this growth, networking researchers are faced on the increasingly daunting task of controlling and managing huge amounts of traffic than expected. Due to this unexpectedly huge amount of traffic, nodes are congested. As a result, users can not get enough quality of service (QoS) required for their applications. To satisfy the users demand, many researches have implemented single-path routing algorithms. Furthermore, multi-hop routing algorithms [1-5] are discussed to control the congestion using disjoint path finding algorithms. In existing disjoint path finding algorithms, the quality (throughput, delay, and jitter) of links and router nodes (routers) are taken as metrics. The algorithms cannot be adopted to the environment where the traffic is dynamically changed. The measurements used in the algorithms are micro level, i.e. traffic information on links and nodes are measured. In this paper, we propose a new *maximum disjoint path algorithm* based on the zone concept. A path is referred to as Zone-based maximum disjoint path if there is minimum number of intermediate zones from source to destination. Using the Zone-based Multi-path Routing (ZMR) algorithm, disjoint paths are found based on states of zones. Each zone has a state *congested*, *no congested*, or *congested a little* [8]. A state of a zone is represented just in terms of a numerical variable. In Fig. 1, let us consider five paths P_1, P_2, P_3, P_4 and P_5 from a source zone Z_s to a destination zone Z_d. Here, in Fig.1 intermediate zones in P_1, three intermediate zones in P_2, four intermediate zones in P_3, five intermediate zones in P_4 and five intermediate zones in P_5, respectively. Let G_1, G_2, G_3, G_4, and G_5 show states of P_1, P_2, P_3, P_4, and P_5 respectively. Suppose that the path P_2 is the fastest in the set $P_{sd} = \{P_1, \ldots, P_5\}$, i.e. P_2 is not congested. The path P_3, P_4, and P_5 disjoint with fastest path P_1. Here suppose the path P_3 is the minimum disjoint with P_1. First, messages are routed from a source zone Z_s to a destination zone Z_d through the fastest path P_1. If the path P_1 does not support enough QoS due to congestion in some zone or inter-zone link of the path P_1, the minimum disjoint path P_2 is taken and messages are routed through the path P_2. In this paper, we discuss how to find the fasted path and minimum disjoint path in a macro-level network of zones.

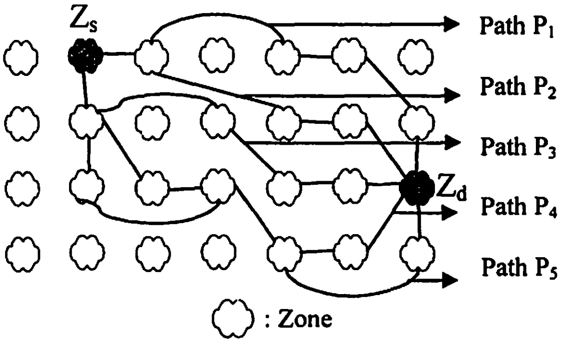

Fig. 1: Maximum disjoint path selection

The remainder of this paper is organized as follows: In section 2, we briefly review some related approaches of routing methods. In section 3, we discuss some basic definitions. In section 4, we discuss our previous work. In section 5, we present the proposed method. In section 6, we present our simulation results and analysis. And we finally conclude the paper in section 7.

2. Related Works

J. Chen et al. [1] present a multi-path forwarding method that uses small, fixed length path identifiers and requires router state space proportional to the number of different paths for each destination. Therefore, a source node can decide the best path to send the data to the destination.

I. Cidon et al. [2] compare the results of analysis between single path routing and multi-path routing using poisson model. The analysis showed the multi-path reservation algorithms perform better throughput than single-path reservation algorithms.

S. Murthy et al. [3] present a new framework for the modeling of multi-path routing in connectionless network that dynamically adapt network congestion. The dynamic maintenance of multiple loop-free paths attempt to reduce the delay from source to destination.

D. Sidhu et al. [4] present a distributed distance vector algorithm for finding multiple node disjoint paths in a computer communication network. The algorithm also considers the shortest path as one of the disjoint paths. The authors claimed that using their proposed algorithm, congestion is reduced in a network and reduce the probability of dropped packet.

S. Vutukury et al. [5] present a distributed routing algorithm for computing multiple paths that need not have equal length between each source-destination pair in a computer network such that they are loop free at every instant-in steady state as well as during network transitions.

W. T. Zaumen et al. [6] propose a new distributed algorithm for the dynamic computation of multiple loop-free paths from source to destination in a computer network and compared with the idle link state algorithm and the diffusing update algorithm.

3. Basic Definitions and Concept

A network is composed of nodes interconnected in links with other nodes. An autonomous system (AS) is a subset of a network which is managed in some policies. A zone is defined to be an autonomous systems or a collection of autonomous systems. A zone is connected to another zone through gateways. The connection is modeled to be a link between the zones. A pair of zones is connected iff there is a link between the zones.

A source node sends a message to a destination node in a network. Here, zones including a source node and destination node are referred to as source zone Z_s and destination zone Z_d of the message m, respectively. The message m is transmitted through intermediate zones from Z_s to Z_d. A path from Z_s to Z_d is a sequence $<Z_s, Z_1, Z_2, \ldots, Z_n, Z_d>$ of zones where Z_s and Z_1, Z_n and Z_d are connected by links

Each zone Z_i is characterized by state. There are three states, *congested, not congested* and *congested a little.* Each state of a zone is uniquely represented by a numerical value. Here, value v(s) denote state value of a state *s*, where *s* belongs to *congested, not congested,* and *congested a little*. The inequality of states is as follows: v(not congested) < v(congested a little) <v(congested). Let $\mathbf{P_{sd}}$ be a collection of possible paths from a zone Z_s to another zone Z_d. Each path P_i is denoted by a sequence $<P_1, P_2, \ldots, P_n>$. A path P_i is referred to as fastest iff (if and only if) the state value state (P_s) of P_i is the minimum in the path set $\mathbf{P_{sd}}$. A path P_i is referred to as disjoint in $\mathbf{P_{sd}}$ iff there is no intermediate zones from source zone Z_s to destination zone Z_d in P_i (i=1,n). A path P_i (let, i=1) in $\mathbf{P_{sd}}$ is referred to as maximum disjoint with P_i ($i \neq 1$) iff the path P_i (i=1) is the fastest in paths which disjoints with P_i ($i \neq 1$).

4. Our Previous Works

In the Ryuki model [7], zone-based network performance metrics such as zone temperature, zone pressure and zone density are introduced to measure the zone performance in the Internet. Zone temperature shows the utilization of the zone. Pressure indicates the flow activity of a zone. The higher pressure, the slower traffic, smoothness is slower. The larger density, the more usable bandwidth of the zone.

In the Zone-based congestion control method [8], the authors discuss how to control the zones capacity such that the sender can send its data in a reliable manner even if the link or the router between the source and destination zone is highly congested or broken down. If there is no alternate link to the destination, users have to wait for the mechanical solutions for the recovery, which will take long time and is expensive as the congestion is at a micro-level.

Zone-based quality of service (QoS) is discussed in the paper [9]. QoS related information (throughput, delay etc.) are understandable only for technical people like network engineers, but not for non-technical people. In order to alleviate this problem, we defined QoS metric, which is easily understandable for not only the technical but also non-technical people. Non-technical people are just required to have knowledge on web search and real weather forecasts.

In the paper [10], we proposed a method called 'zone-based load balancing' for the sharing of capacity among zones of a communication network. If a zone owner wishes to sell capacity for a specified period of time to a number of different zones, or if zones cooperate to build a network to be shared among themselves, load can be balanced performed to mediate between rapidly fluctuating costs and the capacity of zone which might be traded. If the source zone does not have the multi-path route to the destination, the algorithm cannot be adopted.

In addition, we do not discuss which path to be used to transmit data to the destination. To overcome these difficulties, we propose a new method called Zone-based Multi-path Routing (ZMR) for congestion control in the next section.

5. Zone-based Multi-path Routing

5.1. Route discovery

We discuss the Zone-based Multi-path Routing (ZMR) algorithm to find multiple routing paths from a source zone Z_s to a destination zone Z_d which disjoint with each other and support better QoS than the other possible paths from Z_s to Z_d. The Zone-based Multi-path Routing (ZMR) is an on demand routing protocol to build multiple routes using the request/reply mechanism. If the source zone Z_s needs a route to the destination zone Z_d but no route information is known, the source zone Z_s floods a ROUTE REQUEST (RReq) message to the whole network. Because the message is flooded, duplicate packets that traverse through different routes reach the destination zone. The destination zone selects multiple disjoint routes and sends a ROUTE REPLY (RRep) message back to the source zone via each of the chosen routes.

5.2. Route request (RReq)

The main goal of Zone-based Multi-path Routing (ZMR) is to develop maximum disjoint multiple paths, so that no zone will be congested, and available zone will be used efficiently. To achieve this goal in on-demand routing schemes, the destination zone has to obtain the entire information, i.e. a path of nodes to select the optimal routes. We take the source routing approach where the information of the zones that consist of the route is included in the RReq packet. In addition, intermediate zone are not allowed to send RReps back to the source zone even if they have some route information to the destination zone.

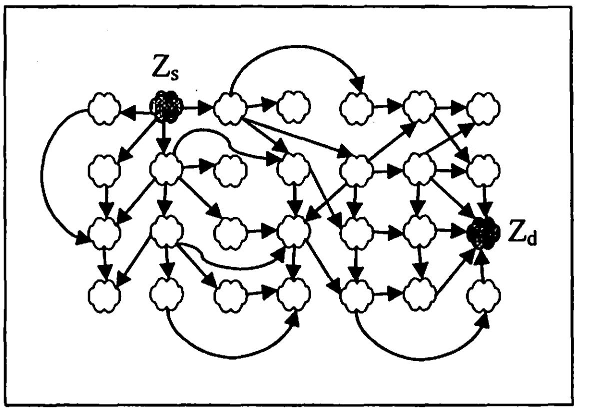

Fig. 2: Route Request (RReq)

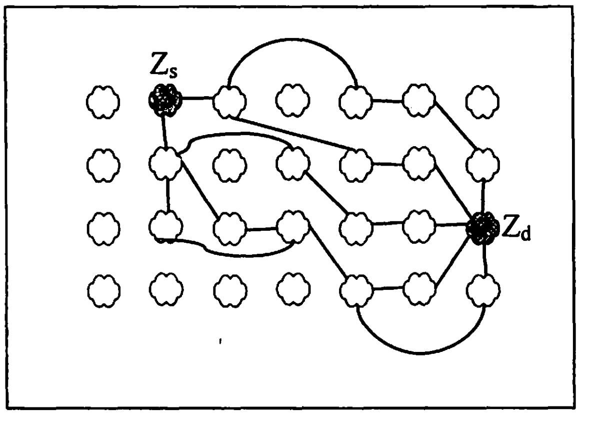

Fig. 3: Available Paths

If the source zone has data to send but does not have the route information to the destination zone, the source zone transmits a route request (RReq) message to the destination zone. The message contains the source ID and a sequence number that uniquely identifies the message. If a zone other than the destination zone receives an RReq, if the zone had not received the RReq message the zone appends its ID to the message and then rebroadcasts the message.

5.3. Route selection method

In our proposed method, the destination zone selects two routes that are maximum disjoint. Here, more than two routes can be chosen, but we limit the number of routes to two for simplicity in this document. One of the two routes is weighted the lowest routes; the path taken by the first RReq which the destination zone receives. We use the lowest weighted path as one of the two routes to minimize the route acquisition weight required by on-demand routing protocols as following steps:

(a) On receiving the first RReq, the destination zone record the entire path and sends an RRep to the source zone via this route. The zone IDs in the entire path is recorded in the RRep, and hence the intermediate zones can forward this packet using this information.

(b) The destination zone waits for a certain duration of time to receive more number of RReqs and learn all possible routes;

(c) The destination zone then selects a route that is maximum disjoint to the route that is already obtained. The maximum disjoint route can be selected because the destination zone knows the entire path information of the first route and all other candidate routes.

If there are more than one route that are maximum disjoint with the first route, one of the routes with the shortest hop distance is chosen. If there still remain multiple routes that meet the condition, a path where the RReq to the destination zone is delivered the quickest is selected. The destination zone then sends another RRep to the source zone via the second route selected.

6. Simulation: Results and Analysis

In this section, we evaluate Zone-based Multi-path Routing (ZMR) through simulation. We analyze how the state (congestion, congestion a little, no congestion) of the zone varies from the zone temperature and zone density.

6.1 Results

In this section, we explain the obtained results from the simulation. Fig. 4 shows the relation between temperature, density, congestion level vs. traffic load. From this figure, we can know the change of temperature, density and congestion level by the amount traffic load. Example: if 70% traffic inject in the zone, then from the simulation results, temperature is .468, density is .230 and congestion level is .074

In Fig. 4, if the traffic load is in the range of 0.0 to 0.2, temperature and density is high, and congestion state is 'no congestion' in this situation, zone require more traffic. If the traffic load is between 0.2 and 0.4, temperature increases up to the maximum capacity of the zone and density is little low, in this situation applications using maximum capacity of the zone and the state is 'Congestion free'. In the case of traffic load in between 0.4 and 0.8, temperature is slowly decreasing and density is slowing down, so delay will be little high and the state is 'Pre-congestion'.

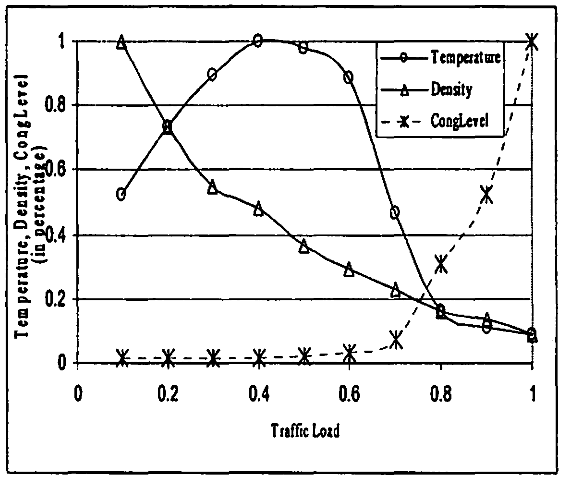

Fig. 4: Congestion level of a single zone comparing with different percentages of traffic load

Therefore, applications cannot inject traffic to prevent from the zone congestion. Finally, if the traffic load is in the range of (0.8, 1.0), zone is in congestion state, because temperature and density is very low. i.e., longer delay due to congestion. Hence, no traffic can enter in this situation.

6.2 Analysis of route selection

Following table shows the optimum path to the destination.

Table 1: End-to-End multi-path congestion cost

	CongCost of Intermediate Zones					ConCost (S_2D)
Path1	.074	.522	.014	.016	-	0.500
Path2	.074	.522	.522	-	-	1.116
Path3	.074	.014	.0166	.022	-	0.124
Path4	.074	.014	.022	.014	.016	0.140
Path5	.074	.014	.022	.014	.311	0.435

Table 1, shows the total congestion cost of five paths Path1, Path2, Path3, Path4 and Path5 from a source Z_s to a destination zone Z_d. Each path has different numbers of intermediate zones with different values of congestion cost. From the table, it is clear that minimum number of intermediate zones with higher congestion cost of a path always do not provide minimum congestion costs, where maximum number of intermediate zones with lower congestion cost of a path can provide low congestion cost in communication. Even if the same number of intermediate zones between source and destination shows different value of congestion costs. For example, Path1 and Path3 have same number of intermediate zones but different values of congestion costs. By comparing five paths, the first selected route is Path3 and second selected route is Path4 by the destination zone according to the lowest weighted path (congestion costs equals 0.124) as shown in the table.

7. Conclusion

In this paper, we have shown how to route traffic according to the weight of path activity. Current Internet traffic flows are routed by the estimated value of a single network device, i.e., a router or a link between two nodes. In the zone-based multi-path routing method, multiple states of a zone are used to estimate the weight of path to route the traffic. This study is the first step in quantifying zone-based multi-path routing for congestion control as well as resource efficiency for the Internet users.

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