Load Balancing for Zone Routing Protocol to Support QoS in Ad Hoc Network

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Abstract: Application Routing Load Balancing (ARLB) is a novel load balancing mode that combines QoS routing and load balancing in per application to support QoS for real-time application based on wired network.

Zone Routing Protocol (ZRP) is a recent hybrid proactive/reactive routing approach in an attempt to achieve scalability of ad-hoc network. This routing approach has the potential to be efficient in the generation of control traffic than traditional routing schemes. Up to now, without proper load balancing tools, the ZRP can actually guarantee QoS for delay-sensitive applications when congestion occurred in ad-hoc network.

In this paper, we propose the ARLB to improve QoS for delay-sensitive applications based on ZRP in ad-hoc network when congestion occurred and to be forwarding mechanism for route coupling to support QoS for real-time applications. The critical point is that the routing metric of ARLB is originally designed for wired network environment. Therefore, we study and present an appropriate metric or cost computation routing of ARLB for recently proposed ZRP over ad-hoc network environment.

1. Introduction

Nowadays, the demand of accessing the Internet is more increasingly for anywhere. This has led to G. Pei and M. Gerla consider the mobility management in large hierarchically organized wireless multihop networks, which enables ad hoc network to communicate with public Internet backbone by using nodes G to be gateway [1] as shown in Figure 1.

To take advantage of availability of gateway resources, one critical point is how a node that is desired to access the Internet can exploit the benefit from growth of the gateways. One solution is a load balancing method. The following is the related papers.

In [3] A. Zhou and H. Hassanein present a new on-demand routing protocol and metric or cost computation for routing in wireless ad-hoc networks known as Load-Balanced Ad-Hoc Routing (LBAR) that provides ability of path maintenance using another route to be redundant routes when a broken path is occurred. Additionally, LBAR is designed for finding a path with the least traffic to support delay-sensitive applications.

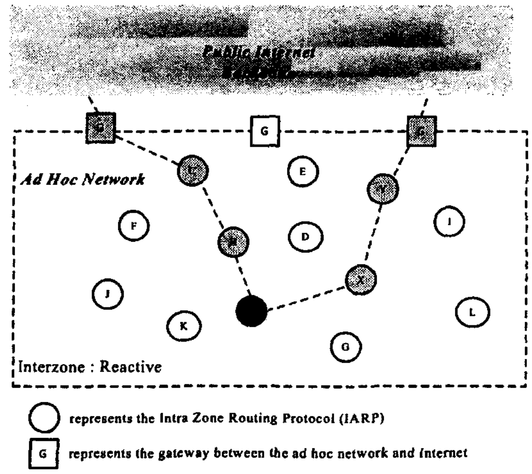

Figure 1. Interconnection between ad hoc network that uses ZRP routing and Internet with ARLB

In [4] M. Pearlman and Z. Haas propose the load balancing in per-packet modes for a route coupling for ZRP. However, a nature of the per-packet mode [7] introduces a probability of out-of-order packet delivery at destination [2] and leads to be misinterpreted by TCP as network congestion, which result in degrade its capability of transmission rate. Furthermore, QoS of delay-sensitive applications is degraded when packets arrive out-of-sequence at destination.

In [2] S. Chimmanee and K. Wipusitwarakun present a novel load balancing in per-application mode to support QoS for real-time application over the Internet environment and introduce a metric to evaluate cost for each routes based on Internet backbone characteristic. Since delay-sensitive applications is not appropriate for long waiting re-sequence of packets that arrive out of sequence at destination, one merit of ARLB is reducing a possibility of packets arriving out of sequence when compares with per-packet load balancing mode.

Until now, there are no proper load balancing methods for exploiting availability of network resources to increase throughput of system and reduce end-to-end delay to support QoS for real-time application based on ZRP in ad hoc network. Hence, this paper presents the ARLB load balancing in per-application mode to support QoS for real-

time application based on ZRP. In order to allow ad hoc network can connect to Internet by exploiting availability of network resources to increase throughput and reduce end-to- end delay when congestion occurred in ad-hoc network. *In other words, this paper proposes the idea to improve* QoS for delay-time sensitive based on ZRP in ad-hoc network by using the load balancing tool

One critical point is that the characteristic of ad-hoc network and the Internet is rather different. Because ad hoc network is a wireless network while traditional Internet is a fixed network. In addition, ZRP is the hybrid routing approach that is different from the traditional Internet routing.

Thus, the proposed metric formula in [2] is not *appropriate to be implemented directly in the ZRP since it* is designed for only traditional routing protocol. This leads the paper to research an appropriate metric formula for evaluating cost of each Alternate Route Path (ARP) route set [4] to pick up two optimal ARP route set from all of ARP route sets for supporting route coupling approach.

2. ARLB for ZRP in ad-hoc network

In general, there are three types of existing routing protocols. The first routing protocol is the proactive protocols, which continuously attempt to update routing table to evaluate the routes within the network. This method allows a packet to be routed to the desired destination immediately since the route is already known. The distance-vector and link state protocols are example of this routing protocol.

The second routing protocol is the reactive protocols (also called on-demand), on the other hand, the route will be find or searched when a packet needs to be routed to the desired destination. The routing protocols have also been designed for the ad-hoc network environment, such as [3].

The third routing is the hybrid routing protocol is to combine both proactive and reactive routing protocol, which is suitable for a wide variety of mobile ad-hoc networks. ZRP is an example of this routing protocol.

ZRP consists of the IntrA Zone Routing Protocol (IARP) that use the proactive to be routing protocol within zone and IntEr Zone Routing Protocol (IERP) that uses the reactive to be routing protocol among zones. IERP uses a query-response mechanism to discovery route on demand. A single route query can return from multiple route replies and then discovery paths are a list of APR route sets without any advance route-computation [4]

2.1 Routing Protocol

IntrA Zone Routing Protocol (IARP): In [5] provides specifications for both distance-vector and link state protocols of IARP. In this paper, the IARP is implemented by a modified version of a link state scheme called "Open-Short Path First (OSPF)" [6], since it is a popular Internet routing protocol used widely in the Internet.

IntEr Zone Routing Protocol (IERP) : In [3] presents the on-demand routing method that find a path that would reflect least traffic load to data packets can be routed with least delay. In this paper, the LBAR routing is used as reactive routing for IERP since it is designed for supporting delay-sensitive applications.

Gateway node: In[1] present the G node, which enables ad hoc network to communicate with public Internet backbone by using nodes G to be gateway. In this paper, OSPF is also used as routing protocol for the G node.

2.2 Metric for routing

Currently, ZRP can supports QoS routing through the collection of various route quality metrics in both proactive and reactive routing components depending on the implementation of routing protocol or QoS routing mechanism [5]. Consequently, we study the current metric or cost computation for routing to find the proper metric for ARLB in ad-hoc network.

OSPF Metric : One method of calculating the cost or metric of OSPF is to divide one hundred million by the bandwidth of the interface [6][8].

Thus, the calculating a cost or metric of OSPF, $C_{(OSPF)}$, can be defined as

$$C_{(OSPF)} = 10^8 / \mathrm{BW} \qquad (1)$$

Where BW represents bandwidth in bits per second.

LBAR Metric : In [3] present the new metric for routing that was developed for wireless ad-hoc networks.

Activity, A_i, is a number of active routes through node i. The greater the value of activity is, the more traffic passing through node i would be.

Traffic interference, TI_i is the sum of activity of neighboring nodes of node i, which is calculated as:

$$TI_i = \sum_{\forall j} A_j^i \qquad (2)$$

Where j is a neighbor node of i

The calculating a cost of route k , $C_{(LBAR)}$, can be defined as

$$C_{(LBAR)} = \sum_{i \in k} (A_i + TI_i) \qquad (3)$$

Where i is a node on route k.

2.3 ARLB Metric

In wired network, packet delay is caused from traffic load at the current node. In wireless ad-hoc network, on the other hand, the packet delay is also caused from traffic load at neighboring node [3]. Thus, the metric of LBAR is more suitable to used as metric for ARLB in ad-hoc network environment. However, LBAR metric was design without considering capacity of bandwidth like OSPF. Therefore, this paper present a new metric for wireless ad-hoc network area by considering both capacity of bandwidth and traffic load from neighboring node.

ARLB Metric for ad-hoc network area: In LBAR metric, the best-route is the path that encounters the minimum traffic load in transmission and minimum inference by neighbor nodes. This means that if there are more activity (A_i) paths or activity of neighboring node, the capacity of bandwidth of transmission would be shared or degraded. The bandwidth that is considered number of A_i and neighboring nodes, $BW_{(adhoc)}$, can be defined as

$$BW_{(adhoc)} = BW / C_{(LBAR)} \quad (4)$$

Where BW represents bandwidth in bits per second as in Eq.(1).

The ARLB metric for ZRP area that considers both ad-hoc network characteristic factor and the capacity of bandwidth factor, and can be defined as OSPF metric in Eq.(1) as follows.

$$C_{(adhoc)} = 10^8 / BW_{(adhoc)} \quad (5)$$

Metric for Gateway node: Since OSPF is used as routing protocol for the gateway node. Thus, the calculating a cost or metric for gateway node, $C_{(G)}$, can be defined as

$$C_{(G)} = 10^8 / BW \quad (6)$$

Where BW represents bandwidth in bits per second.

ARLB metric: total metric formula for all routes including both ad-hoc network area and gateway node ,$C_{(Sanon)}$, can be defined as

$$C_{(Sanon)} = C_{(G)} + C_{(adhoc)} \quad (7)$$

2.4 ARLB algorithm

Alternate Path Route (APR) Route-set construction:
a list of APR route sets that are feasible routes from source to destination will be created by the routing protocol. And ARLB will pick up only two feasible routes that are lower cost because they are best-route.

Forwarding packet to support the routing coupling:
ARLB controls the following two modes.

- Per-application mode
- Per-destination mode [6]

1) Per-application load-balancing mode is designed to forward packets based on the route coupling with regarding to property of application and characteristic of network to support QoS.

Classification of Applications are classified into the three groups as follows:

- *Group I* applications have small packet size, are time-delay sensitive and have low volume-traffic.
- *Group II* applications have large packet-size, are non-delay sensitive and have high volume-traffic.
- *Group III* is for other applications.

Forwarding method

- Group I (VoIP, Video, DNS and Telnet) is forwarded to the link with a lower cost.
- Group II (FTP, SMTP and HTTP) is forwarded to the link with a higher cost.

2) Per-destination load-balancing mode [2][6]
Forwarding method

- Group III (other traffic) is forwarded to the both routes to optimize the link with per-destination mode.

3. Performance Evaluation of ARLB

3.1 Performance comparison between ARLB with LBAR metric

Our simulation of this experiment are constructed under the following conditions
1) In ad-hoc networks: ad-hoc network are run by using with densities of 50 nodes. The transmission rate is randomized either 2 or 11 Mbps. Mobiles can communicate only within range of 250 m. A Carries Sense Multiple Access with Collision Detection (CSMA/CD) is used to transmit packets. We use a packet rate of 4 packets/sec for communication. 2) In this experiment, ad-hoc network run by using only on-demand routing to evaluate only metric for routing. 3) Gateway node(G node): there are 3 gateway nodes under their capacity bandwidth at rate of 2 Mbps. 4) Source node in ad-hoc network needs to send packets to the Internet by via the existing gateway nodes. The source node uses both ARLB and LBAR metric for find the couple routes between from that node to gateway node. In this experiment, we measures the access bandwidth of the selected route coupling between source node and destination gateways.

3.2 Performance Comparison between ARLB with per-packet load-balancing method

Our simulation of this experiment are constructed under the following conditions
1) In ad-hoc networks: ad-hoc network are run by using with densities of 50 nodes. The transmission rate is randomized either 2 or 11 Mbps. Mobiles can communicate only within range of 250 m. A Carries Sense Multiple Access with Collision Detection (CSMA/CD) is used to transmit packets. We use a packet rate of 4 packets/sec for communication. 2) In this experiment, ad-hoc network run by using ZRP routing to evaluate performance of ARLB with per-packet mode for ZRP. 3) Gateway node(G node): there are 3 gateway nodes and their capacity bandwidth is randomized within the range of 2,8 and 10 Mbps. 4) Source node in ad-hoc network needs to send packets to the Internet by via the existing gateway nodes. The source node uses the ARLB metric to find the couple routes to gateway node and then load balancing tool (ARLB and per-packet mode) are used to compare their performance. In this experiment, we measures the end-to-

end delay of VoIP packet sent from the source node to destination node in the Internet.

4. Simulation Results

4.1 Performance evaluation of selecting the route coupling using ARLB and LBRA metric

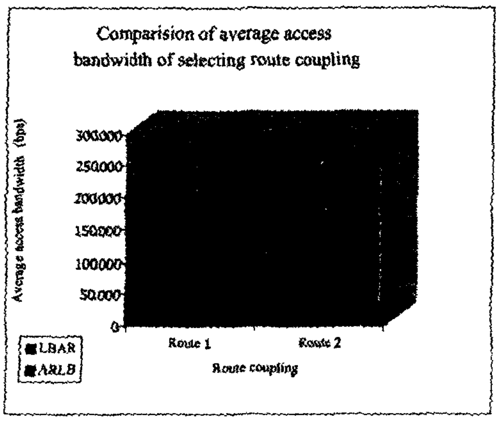

Figure 2: Comparison of the average access bandwidth of selected route coupling of LBAR with ARLB metric.

4.2 Performance Evaluation of ARLB and per-packet load-balancing mode

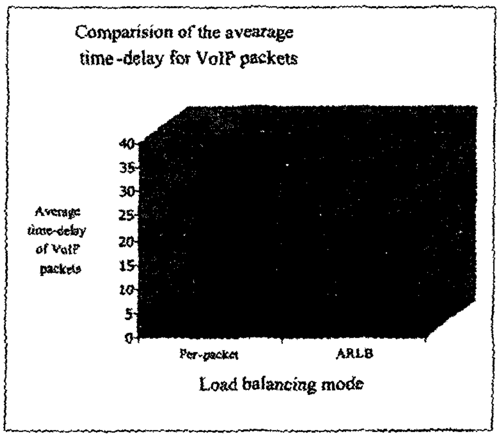

Figure 3: Comparison of the average delay of VoIP packets of per-destination mode with ARLB mode.

5. Conclusion

In this paper, we propose ARLB to support QoS for delay-sensitive applications by increasing throughput of system and reduce end-to-end delay when congestion occurred in ad-hoc network. Since the metric for routing of ARLB is based on the traditional Internet routing and wired network, this led us to study the existing metrics for routing for ad-hoc network and find that LBRA is appropriate metric for ARLB since it is designed for supporting delay-sensitive application in ad-hoc network characteristic. However, the LBRA is designed without considering the capacity of bandwidth factor. Thus, this paper presents a novel metric for routing based on ad-hoc network by considering both capacity of bandwidth transmission and traffic load from neighbor node that is characteristic of ad-hoc network unlike wired network characteristic.

Based on simulation result, there are two topics. First topic is comparison of access bandwidth of the selected route coupling using LBRA with ARLB metric. We see that ARLB metric can select the couple routes with bandwidth capacity higher than those by LBRA up to 40 % since ARLB metric does not only consider traffic load factor but also consider the capacity of bandwidth factor. The second is comparison of end-to-end delay of VoIP packets sent from source within ad-hoc network to gateway nodes of ARLB mode with per-packet mode. We see that average time-delay of VoIP packets of ARLB was less than that of per-packet mode up to 45 % because the high-volume traffics such as ftp are not forwarded to the same link as VoIP traffic. Moreover, packets to the same destination are forwarded to the same route in ARLB. This consequently reduces a possibility of out-of-order arriving packets at destination, while per-packet method is based on round robin fashion and results in high possibility of out-of-order packets.

ARLB will be studied to be dynamic adaptive control for adjusting applications between groups in order to reduce end-to-end delay of delay-sensitive applications in further work.

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