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Fair Packet Distribution on Multi-interfaced Mobile Router for Mobile Networks

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***Abstract*—**This paper proposes a fair packet distribution scheme on a multi-interfaced mobile router (MMR) for mobile networks. In the proposed scheme, the MMR with multiple heterogeneous wireless network interfaces effectively and fairly distributes incoming packets over end-to-end multi-path. Each network interface is considered to have a distribution counter associated with corresponding end-to-end path. This distribution counter varied by both weighted capacity and distributed packets is used to determine if a network interface has enough credits to distribute incoming packets on corresponding end-to-end path. As a useful design parameter, the capacity unit can be shown to make the performance of the proposed scheme as good as possible. Through computer simulations, it is shown that the proposed scheme can distribute well randomly incoming packets over end-to-end multi-path and can outperform the simple weighted packet distribution scheme.

Keywords : Packet Distribution, Network Mobility (NEMO), Multi-interfaced Mobile Router, Heterogeneous Wireless Networks.

1. Introduction

In the near future, airplanes, automobiles, and even people will carry entire networks of IP devices that connect to the Internet, which is called a mobile network. To deal with the mobility support of mobile networks, the Network Mobility (NEMO) techniques have been researched [1]-[6]. In the NEMO, the mobile router (MR) is capable of changing its point of attachment to the Internet without disrupting higher layer connections of attached devices. Therefore, mobile nodes (MNs) inside a mobile network are unaware of their network's mobility; however, they are provided with uninterrupted Internet access even when the network changes its attachment point to the Internet.

This paper considers the mobile network with a multi-interfaced mobile router (MMR) as shown in [4]-[6]. In addition, to consider the heterogeneous wireless network environment [7]-[9], the MMR can be assumed to have multiple heterogeneous wireless network interfaces. Therefore, the MMR establishes simultaneously multiple paths to the Internet through external wireless interfaces such as wireless metropolitan area network (WMAN) and wireless wide area network (WWAN) with high mobility and wide coverage. However, due to bandwidth constraints of multi-path through external wireless interfaces, the MMR might require a bandwidth aggregation to get sufficient bandwidth for MNs' demanding inside a mobile network. As shown in [10]-[14], the bandwidth aggregation requires generally several functions such as bandwidth estimation, packet distribution, packet reordering, etc. Among them, this paper focuses on the packet distribution scheme which effectively and fairly distributes packets on the appropriate end-to-end path through the corresponding network interface.

Therefore, this paper proposes a packet distribution scheme on the MMR with heterogeneous wireless network interfaces for mobile networks. Since the MMR is likely to have limited resources compared with a general router, the proposed scheme adopts the frame-based behavior that has lower complexity than the priority-based behavior. In the proposed scheme, the MMR with multiple heterogeneous wireless network interfaces effectively and fairly distributes packets over end-to-end multi-path. Each network interface is considered to have a distribution counter associated with the corresponding end-to-end path. This distribution counter is used to determine if a network interface has enough capacity to distribute packets on the corresponding end-to-end path. The distribution counter can get credits by the weighted capacity in bytes. The weighed capacity is operated at the byte level and is added more to the distribution counter with higher weight than that with less weight. On the other hand, the distribution counter is decreased by the size of packets being distributed. Thus, the distribution counter for each network interface is varied by distributed packets as well as weighted capacity.

In the proposed scheme, performance indices can be defined by ratio and amount of distributed packets, packet loss, and throughput. The capacity unit is shown to be a useful design parameter to make the performance of the proposed scheme as good as possible. To show how the capacity unit affects on performance indices, computer simulations are performed for some cases according to the capacity unit, which can provide practical guidance on the choice of a capacity unit. In addition, the proposed scheme is compared with the simple weighted packet distribution scheme. From simulation results, the proposed scheme is shown to be superior to the simple weighted scheme.

The paper is organized as follows. In Section 2, a fair packet distribution scheme on the MMR with heterogeneous wireless network interfaces is proposed for mobile networks. In Section 3, extensive computer simulations are performed. Finally, concluding remarks are made in Section 4.

2. Introduction

As shown in Figure 1, this paper considers the mobile network where the MMR has multiple heterogeneous wireless network interfaces. The MMR establishes multiple communication paths to the Internet through external wireless interfaces such as WMAN and WWAN with high mobility and wide coverage. In this mobile network environment, a fair packet distribution scheme on the MMR with heterogeneous wireless network interfaces is proposed for mobile networks.

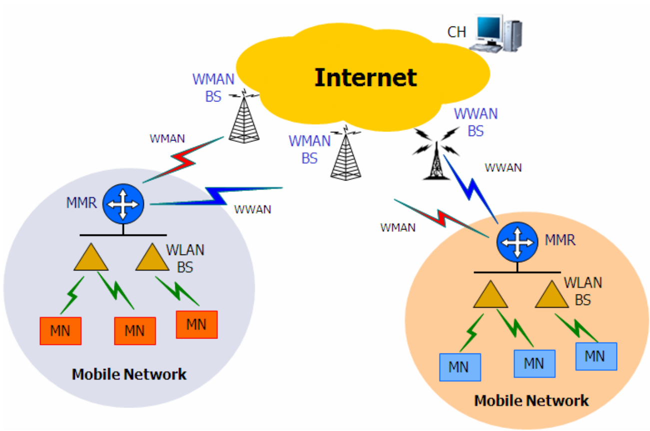

Figure 1. Mobile network environments with heterogeneous wireless networks

2.1 Design Parameters

In the proposed scheme, the MMR distributes packets effectively and fairly on the appropriate end-to-end path through the corresponding network interface. Each network interface is considered to have a distribution counter associated with the corresponding end-to-end path. This distribution counter is used to determine if a network interface has enough capacity to distribute packets on the corresponding end-to-end path. The distribution counter can get credits by the weighted capacity in bytes. The weighted capacity is defined by *Weighted capacity = Capacity unit * Weight*. The capacity unit in bytes is a useful design parameter and thus can affect on the performance of the proposed scheme. The weight is determined proportionately from the estimated available bandwidth of end-to-end paths. The weighed capacity is operated at the byte level and is added more to the distribution counter with higher weight than that with less weight. On the other hand, the distribution counter is also decreased by the size of packets being distributed. Thus, the distribution counter for each network interface is varied by distributed packets as well as weighted capacity.

2.2 Operation Procedure and Example

The operation procedure for each round is as follows. For the first path, packets are distributed when the distribution counter is greater than the incoming packet's size. If it is lower, the distribution counter is increased by the weighted capacity and then the incoming packet is distributed on the current path. Then the distribution counter is decreased by the size of packet being distributed. If the distribution counter is still lower than the incoming packet's size, the incoming packet held back until the proposed scheme moves on the next path. After visiting all paths, the round is finished. The above operation procedure in next round is repeated when there are incoming packets.

As an example, the MMR is assumed to have three heterogeneous wireless network interfaces and thus there are three communication paths. These paths are called the Green (high bandwidth), Yellow (medium bandwidth), Red (low bandwidth) paths, respectively. Since this paper focuses on the packet distribution scheme, available bandwidths for three paths through corresponding interfaces are assumed to have fixed weight ratio 4:2:1. The capacity unit is set by 256 bytes and thus these paths have weighted capacity 1024, 512, 256 bytes, respectively. All initial values of distribution counters, denoted by $DC_{g,y,r}$, and total amount of distributed packets, denoted by $ADP_{g,y,r}$, for three paths are set with 0. There are four kinds of packet type with different sizes such as 256, 512, 768, 1024 bytes.

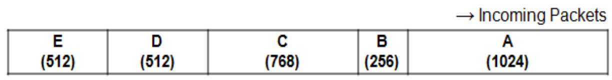

Figure 2. Incoming packets

As shown in Figure 2, incoming packets are waiting to be distributed to the most appropriate path. The 1st round is operated. At Green path, the weighted capacity is added and thus the distribution counter, DC_g, is 1024. Then, since the DC_g is not less than the incoming packet's size (1024 bytes), the incoming packet 'A' is distributed to Green path and thus DC_g=0. Currently, total amount of distributed packets to Green path, ADP_g, is 1024 bytes. At Yellow path, the weighted capacity is added and thus DC_y=512. Then, since the DC_y is not less than the incoming packet's size (256 bytes), the incoming packet 'B' is distributed to Yellow path and thus DC_y=256. Currently, ADP_y=256. At Red path, the weighted capacity is added and thus DC_r=256. Then, since the DC_r is still less than the incoming packet's size (768 bytes), move to Green path. Currently, ADP_r=0. The 1st round is done as shown in Table 1. Then, the 2nd round is operated. At Green path, since the DC_g is less than the incoming packet's size (768 bytes), the weighted capacity is added and thus DC_g=1024. Then, the incoming packet 'C' is distributed to Green path and thus DC_g=256. Currently, ADP_g=1792. At Yellow path, since DC_y is less than the incoming packet's size (512 bytes), the weighted capacity is added and thus DC_y=768. Then, the incoming packet 'D' is distributed to Yellow path and thus DC_y=256. Currently, ADP =768. At Red path, since DC_r is less than the incoming packet's size (768 bytes), the weighted capacity is added and thus DC_r=512. Then, Then, the incoming packet 'E' is distributed to Green path and thus DC_g=0. Currently, ADP_r=512. The 2nd round is done as shown in Table I. The operation procedure in next round is repeated when there are incoming packets.

TABLE I. DISTRIBUTION COUNTERS AND TOTAL AMOUNT OF DISTRIBUTED PACKETS

		1st Round	2nd Round
Green Path	DC_g	1024→0	1024→256
	ADP_g	1024	1972
Yellow Path	DC_y	512→256	768→256
	ADP_y	256	768
Red Path	DC_r	256	0
	ADP_r	0	512

2.3 Performance Indices and Useful Design Parameters

There can be four performance indices in the proposed scheme; ratio of distributed packets, amount of distributed packets, packet loss and throughput. Their objectives are described in Table II. Of course, the throughput can be improved as many packets are distributed. However, the improvement of the throughput does not have the meaning if the packet loss increases.

TABLE II. PERFORMANCE INDICES AND THEIR OBJECTIVES

Performance Index	Objective
Ratio of distributed packets	Distributing packets fairly according to the weight ratio of each end-to-end path
Amount of distributed packets	Distributing packets as many as possible over each end-to-end path
Packet loss	Minimizing lost packets on each end-to-end path
Throughput	Maximizing the average rate of successful packet delivery on each end-to-end path

As mentioned before, the capacity unit is a useful design parameter to determine weighted capacity that affect on four performance indices mentioned before. Too big value of the capacity unit can introduce excessive credits for end-to-end paths, which means that network paths have enough credits to distribute packets. Thus, incoming packets are more likely to be distributed simultaneously on every path each round, which cannot provide fair distribution according to weights for network paths. Thus, the ratio of distributed packets can be degraded. In addition, since packets can be distributed too many over each end-to-end path, the performance for packet loss can be degraded. Of course, since packets are distributed too many over each end-to-end path, the throughput can be improved. However, as mentioned before, the improvement of the throughput does not have the meaning since the packet loss increases. On the other hand, too small value of the capacity unit can introduce deficient credits for end-to-end paths, which means that end-to-end paths do not have enough credits to distribute packets. Thus, incoming packets are less likely to be distributed on every paths each round, which can thus degrade the amount of distributed packets. In addition, since the amount of distributed packets over each end-to-end path is not much, the throughput can be degraded whereas the packet loss can decrease. Therefore, the important issue here is how to choose an appropriate capacity unit to make the performance of the proposed scheme as good as possible. Following computer simulations can provide practical guidance on the choice of the capacity unit.

3. Performance Evaluations Through Computer Simulations

In this section, computer simulations are performed to evaluate the proposed scheme. The MMR is assumed to have three heterogeneous wireless network interfaces and thus there are three communication paths. Available bandwidths for three paths through corresponding interfaces are assumed to have fixed weight ratio 3:2:1. To make a clearer verification, 30 simulations are performed and each simulation generates randomly incoming packets with four kinds of packet type with different sizes such as 256, 512, 768, 1024 bytes

3.1 Performance Evaluation According to Capacity Unit

To show how the capacity unit affects on performances indices, computer simulations are performed for three cases according to capacity units such as 192, 256, 320 bytes, respectively. Table III and Table IV show average values for four performance indices for each path. As mentioned before, too big value of the capacity unit cannot provide fair distribution according to weights for each network paths. That is, the ratio of distributed packets is shown to be degraded. In addition, since packets can be distributed too many over each end-to-end path, the performance for packet loss can be degraded. Although the throughput is shown to be improved, the improvement of the throughput does not have the meaning since the packet loss increases. On the other hand, too small value of the capacity unit degrades the amount of distributed packets. In addition, since the amount of distributed packets over each end-to-end path is not much, the throughput is shown to be degraded whereas the packet loss is shown to decrease. The simulation result is shown to be more favourable than other cases when the capacity unit is 256 bytes.

3.2 Performance Comparison

The proposed packet distribution scheme is compared with the simple weighted packet distribution scheme. The simple weighted scheme distributes packets according to only the weight ratio of network paths without the distribution counter and the capacity unit. That is, the simple weighted scheme does not consider the size of incoming packets unlike the proposed scheme. As shown in Table V, the proposed scheme is shown to be superior to the simple weighted scheme for the amount of the distributed packets and comparable for the ratio of distributed packets. As shown in Table VI, the proposed scheme is shown to be inferior slightly to the simple weighted scheme for the packet loss. The proposed scheme is shown to be superior to the simple weighted scheme for the throughput. This observation is from that the proposed scheme distributes packets with the consideration of incoming packets size using the distribution counter and the capacity unit. On the other hand, the simple weighted scheme does not since long-sized packets can be distributed on specific network interface unfairly.

4. Conclusions

In this paper, the fair packet distribution scheme on the MMR with multiple heterogeneous wireless network interfaces has been proposed for mobile networks. The fair packet distribution scheme makes the MMR distribute effectively and fairly incoming packets over end-to-end multi-path. Each network interface has been considered to have a distribution counter associated with corresponding end-to-end path. This distribution counter varied by both weighted capacity and distributed packets has been used to determine if a network interface has enough credits to distribute incoming packets on corresponding end-to-end path. The capacity unit has been shown to be a useful design parameter to make the performance of the proposed scheme as good as possible. Computer simulations have shown that the proposed scheme can distribute well randomly incoming packets over end-to-end multi-path and can outperform the simple weighted packet distribution scheme.

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TABLE III. SIMULATION RESULTS : AMOUNT AND RATIO OF DISTRIBUTED PACKETS

Capacity Unit	Amount of Distributed Packets (Mbytes, Average)				Ratio of Distributed Packets (Average)
	Green Path	Yellow Path	Red Path	Total	
192	8.16	5.11	2.64	15.90	3.10:1.94:1
256	10.01	6.50	3.37	19.88	2.97:1.93:1
320	9.70	7.70	4.17	21.57	2.33:1.85:1

TABELE IV. SIMULATION RESULTS : PACKET LOSS AND THROUGHPUT

Capacity Unit	Packet Loss			Throughput		
	Green Path	Yellow Path	Red Path	Green Path	Yellow Path	Red Path
192	7.8	6.9	7.7	2.17 (72%)	1.36 (68%)	0.70 (70%)
256	8.0	9.0	10.0	2.67 (89%)	1.73 (87%)	0.90 (90%)
320	8.0	970.0	2138.0	2.58 (86%)	1.93 (97%)	III.9797%)

TABLE V. COMPARISON : AMOUNT AND RATIO OF DISTRIBUTED PACKETS

Mechanism	Amount of Distributed Packets (Mbytes, Average)				Ratio of Distributed Packets (Average)
	Green Path	Yellow Path	Red Path	Total	
Proposed Mechanism	10.01	6.50	3.37	19.88	2.97:1.93:1
Simple Weighted	8.47	5.65	2.83	16.95	2.99:1.99:1

TABLE VI. COMPARISON : PACKET LOSS AND THROUGHPUT

Mechanism	Packet Loss			Throughput		
	Green Path	Yellow Path	Red Path	Green Path	Yellow Path	Red Path
Proposed Mechanism	8.0	9.0	10.0	2.67 (89%)	1.73 (87%)	0.90 (90%)
Simple Weighted	7.8	7.3	8.30	2.26 (75%)	1.50 (75%)	0.76 (76%)