Performance Evaluation of the Route Optimization Scheme in Mobile IPv6

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Abstract. The paper presents the performance comparison between the triangle routing and the route optimization. The paper presents not only the analytical models to compare the performance but also the threshold value to decide whether the mobile node had better use the route optimization or not. The model provides the approximate guideline when a network administrator is to implement mobile IPv6 with the route optimization under the given network environments.

1 Introduction

The Internet Engineering Task Force (IETF) has proposed “route optimization” in Mobile IP [1] to solve this “triangle routing” problem [1] that the packets from correspondent node (CN) must be forwarded to the mobile node (MN) via a home agent (HA). The route optimization enables the packets to be delivered directly between the MN and the CN. How effective is the route optimization? And will we always need the route optimization capability when we are to implement Mobile IPv6 under some conditions? There is no concrete answer for such questions so far [3]. Most of works have not presented the exact quantitative results considering various factors such as the number of hops between end-to-end host, the network bandwidth, the size of data packets, and the failure rate of the binding update. Therefore, we propose analytical models to evaluate the performance of the triangle routing scheme and that of the route optimization scheme and show the quantitative results of performance comparison.

2 The Proposed Model

Using the triangle routing as shown in Figure 1 (solid line), the packet destined to the MN is intercepted and tunneled by the HA. The tunneled packet will be forwarded to

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Fig. 1. The Triangle Routing and the Route Optimization in Mobile IPv6

the MN. Using the route optimization, the MN and the CN can communicate directly after using the BU/BA messages as shown in Figure 1 (dotted line).

Destination Option Header, to include Home Address Option [2], should be added to the packet routed from the MN to the CN, while Type 2 Routing Header should be used for the packet routed from the CN to the MN reversely, to carry its home address [4]. Table 1 depicts the notations used in the proposed analytical models.

Table 1. The Notations Used in the Proposed Model

Notation	Description	Value
BW_{wl}	The Average Bandwidth in Wireless Network (Mbps)	10
BW_{wd}	The Average Bandwidth in Wired Network (Mbps) = $BW_{wl} \times 10$	100
p	The Success Probability of the Binding Update Message	0.99
pkt	The Size of Receiving and Sending Data (byte)	
$PMTU$	The Size of Path MTU (byte)[5]	1500
IPH	The Size of IP Basic Header (byte) [5]	40
$MobH$	The Size of Mobility Header (byte) [2]	
$AuthH$	The Size of Authentication Header (byte) [6]	20
$FragH$	The Size of Fragment Header (byte) [5]	8
$DestOpH$	The Size of Destination Option Header (byte) [5]	20
$RoutH$	The Size of Type 2 Routing Header (byte) [2]	24
$IP Tun$	The Additional Size for IP-IP Tunneling (byte) [4]	40
BU_M	The Size of the Binding Update Message (byte) = $40(IPH)+12(MobH \text{ with MH Type}=5)+20(DestOpH)$	72
BA_M	The Size of the Binding Acknowledgement Message (byte) = $40(IPH)+12(MobH \text{ with MH Type}=6)$	52

Equation (1) shows the total costs for sending a BU message and a BA message. The retransmission for BU message failure has exponential back-off time and continues until an MN receives a BA or until a maximum (256 seconds) is reached [3]. Consequently, the cost of the routing optimization procedure is obtained by Equation (2).

$$T_{Msg} = \left\{ \frac{BU_M + BA_M}{BW_{wl}} + (m-1) \times \frac{BU_M + BA_M}{BW_{wd}} \right\} \times \frac{8(bit)}{1000 \times 1024^2 (bps)} \quad (1)$$

$$T_{ROpro} = p \times T_{Msg} + \sum_{i=2}^{10} p(1-p)^{(i-1)} (T_{Msg} + T_w), \quad 1 \leq T_w = 2^{(i-2)} \leq 256 \quad (2)$$

Equation (3) creates temporary variables to keep the final formula simple.

$$\begin{aligned} g1 &= IPH + AuthH + FragH, \quad g2 = IPH + AuthH + FragH + DestOpH \\ g3 &= IPH + AuthH + FragH + RoutH, \quad g4 = IPH + AuthH + FragH + IPTun \\ r1 &= PMTU - g1, \quad r2 = PMTU - g, \quad r3 = PMTU - g3, \quad r4 = PMTU - g4 \\ q1 &= \left\lfloor \frac{pkt}{r1} \right\rfloor \times PMTU + \left(pkt - \left\lfloor \frac{pkt}{r1} \right\rfloor \times r1 \right) + g1, \quad q2 = \left\lfloor \frac{pkt}{r2} \right\rfloor \times PMTU + \left(pkt - \left\lfloor \frac{pkt}{r2} \right\rfloor \times r2 \right) + g2 \\ q3 &= \left\lfloor \frac{pkt}{r3} \right\rfloor \times PMTU + \left(pkt - \left\lfloor \frac{pkt}{r3} \right\rfloor \times r3 \right) + g3, \quad q4 = \left\lfloor \frac{pkt}{r4} \right\rfloor \times PMTU + \left(pkt - \left\lfloor \frac{pkt}{r4} \right\rfloor \times r4 \right) + g4 \end{aligned} \quad (3)$$

Equation (4) shows the total delay required when an MN sends packets to a CN and receives ones from the CN. Equation (5) is obtained by adding the delay required when an MN sends the tunneled packets to the HA to the delay required when the HA sends the packets to the CN.

$$T_{MN:CN} + T_{CN:MN} = \left[\left\{ \frac{q2}{BW_{wl}} + (m-1) \frac{q2}{BW_{wd}} \right\} + \left\{ \frac{q3}{BW_{wl}} + (m-1) \frac{q3}{BW_{wd}} \right\} \right] \frac{8(bit)}{1000 \times 1024^2 (bps)} \quad (4)$$

$$T_{MN:HA:CN} = T_{CN:HA:MN} = \left\{ \frac{q4}{BW_{wl}} + \frac{h \times q1 + (k-1) \times q4}{BW_{wd}} \right\} \frac{8(bit)}{1000 \times 1024^2 (bps)} \quad (5)$$

The total delay (ms) for the packet transmission using the routing optimization and the triangle routing, are obtained by Equation (6) and (7), respectively.

$$\begin{aligned} T_{RO} &= T_{ROpro} + T_{MN:CN} + T_{CN:MN} \\ &= p \times T_{Msg} + \sum_{i=2}^{10} p(1-p)^{i-1} (T_{Msg} + T_w) + \left\{ \frac{q2 + q3}{BW_{wl}} + (m-1) \frac{q2 + q3}{BW_{wd}} \right\} \frac{8(bit)}{1000 \times 1024^2 (bps)} \end{aligned} \quad (6)$$

$$T_{TR} = T_{MN:HA:CN} + T_{CN:HA:MN} = 2 \times T_{MN:HA:CN} = \left\{ \frac{q4}{BW_{wl}} + \frac{h \times q1 + (k-1) \times q4}{BW_{wd}} \right\} \frac{16(bit)}{1000 \times 1024^2 (bps)} \quad (7)$$

3 The Results of Performance Evaluation

We compare the performance of the routing optimization (RO) scheme and the triangle routing (TR) scheme in terms of the total transmission delay for the messages using the corresponding routing path. The difference in the numbers of hops between the MN and the CN with respect to two routing methods is relatively small. For example, m is 5 or 8 when $h+k = 10$, because the HA can be switched due to load balancing.

Fig. 2. (a) The Delay Comparison according to the Size of Transfer Data (b) The Delay Comparison according to the Bandwidth in Wireless Networks

Figure 2-(a) shows that as the size of the data increases, the delay of TR and that of RO do. In Figure 2-(b), the larger the size of the bandwidth is, the smaller the total delay is. Figure 2-(a) provides the threshold values when $p=0.99$ and wireless bandwidth is 10Mbps. Figure 2-(b) shows that the delay of TR is smaller than that of RO with the short term packet (1K), when $p=0.99$ and the bandwidth $BW_{wd} \leq 10$ Mbps.

4 Conclusion

The paper develops the analytical models to compare the performance of the triangle routing scheme and the route optimization scheme, considering several important factors such as the packet type (long or short term) between the MN and the CN, the number of hops between them, the network bandwidth, and the failure rate of the binding update procedure. It presents the threshold value to decide whether the MN should use the route optimization or not under various situations. The model also provides the approximate guideline when a network administrator is to implement mobile IPv6 with the route optimization capability.

References

1. Perkins, C., Johnson, D.B.: Route Optimization in Mobile IP. IETF Internet Draft draft-ietf-mobileip-optim-11.txt (2001)
2. Johnson, D., Perkins, C., Arkko, J.: Mobility Support in IPv6. IETF RFC 3775 (2004)
3. Soliman, H.: MobileIPv6, Addison-Wesley (2004)
4. Perkins, C.: IP Encapsulation within IP. IETF RFC 2003 (1996)
5. Deering, S., Hinden, R.: Internet Protocol, Version 6 Specification. IETF RFC 2460 (1998)
6. Kent, S., Atkinson, R.: IP Authentication Header. IETF RFC 2402 (1998)