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Improving Mobile IP Performance Through Priority Scheduling

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The increasing number of portable computers, combined with the growth of wireless services, makes supporting Internet mobility important. Since a mobile node always changes its point of attachment to the Internet, it may cross a cell boundary during data transmission process. Packets sequence disruption during handover procedure may result in decreasing network performance especially in higher layers protocols. In this paper we investigate the behavior of Mobile IP protocol in presence of route optimization procedure. We discuss the impact of handover process on packets routed from old Foreign Agent to new Foreign Agent after handover and show that using priority scheduling for packets received from the Home Agent and queued at the old Foreign Agent's buffer after handover can reduce the number of disordered packets received at the new Foreign Agent after handover.

Key words: MIPv4, MIPv6, TCP performance, Priority scheduling, Handover

Unaprijeđivanje mobilnog IP-a raspoređivanjem zasnovanom na prioritetima. Sve veći i veći broj prijenosnih računala, kombinirano s razvijanjem bežičnih usluga, čine podršku mobilnom Internet od velike važnosti. Pošto mobilni čvor ima promijenjivu točku spajanja, može se dogoditi da prijeđe granicu ćelije tijekom prijenosa podataka što može izazvati smanjenje kvalitete usluge, pogotovo kod viših slojeva protokola. U ovome članku analizira se ponašanje mobilnog IP-a uz optimizaciju postupka usmjeravanja. Razmatra se utjecaj na razmjenu podataka između starog agenta i novog agenta te se pokazuje da raspoređivanje zasnovano na prioritetima smanjuje broj neraspoređenih paketa.

Ključne riječi: MIPv4, MIPv6, TCP učinkovitost, raspoređivanje zasnovanom na prioritetima, razmjena podataka

1 INTRODUCTION

As the Internet pervades daily more and more, its users are making more and more demands on it to adapt to their life style. Mobile IP has been designed within the IETF to serve the needs of the burgeoning population of mobile computer users who wish to connect to the Internet and maintain communications as they move from place to place. Mobile IP extends IP by allowing the mobile computer to have two addresses, one for identification (home address), and the other for routing (care-of address) [1].We can outline the operation of the basic mobile IP protocol (MIPv4) as follows [2], [3]: Mobility agents (MA) send agent advertisement messages. After receiving an agent advertisement, a mobile node (MN) can determine whether it is attached to the home network (HN) or to a foreign network (FN). When a mobile node is attached to a foreign network, it obtains a care-of address on that foreign network. The mobile node registers its care-of address with its home agent (HA), as shown in Figure (1). The home agent receives all packets distended to the mobile node's home address and tunnels them to the mobile node's care-of address. Mobile IP still has many items that need to be worked on and enhanced such as the security issue and the routing issue. Packets may be lost during handover process [4]. The smooth handover of route optimization procedure, which is proposed by IETF to handle this problem, faces another problem of packets sequence between packets forwarded by the HA to the new foreign agent (FA) after handover and the packets forwarded from old FA to new FA [5]- [7]. Disordered packets causes duplicated ACKs and packets retransmission which may result in degradation of network performance in higher layers protocols. In this paper, we introduce a priority queueing model (for packets received at the old FA after handover) for reducing the number of disordered packets received at the new FA after handover procedure. The rest of the paper is organized as follows: After presenting a motivation in the next section, we introduce the proposed solution in section 3. A priority queueing model is presented in section 4. Sections 5 and 6 give the measurements and numerical examples of the presented model. Finally, section 7 gives the conclusions.

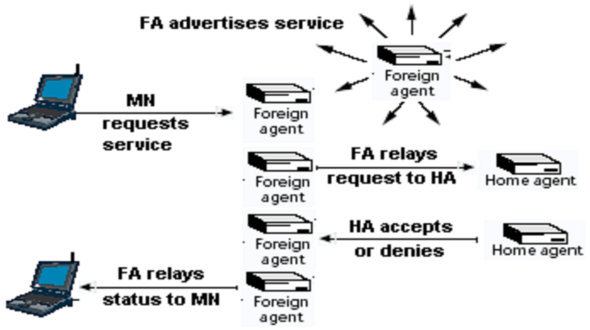

Fig. 1. Registration overview

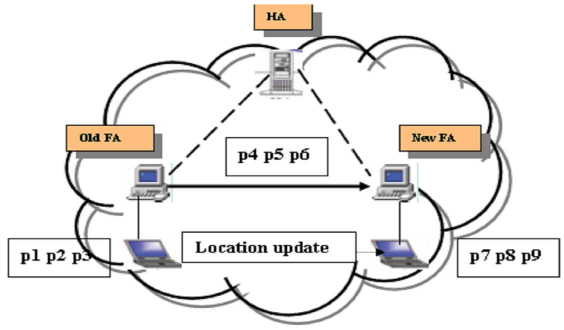

Fig. 2. Disordered packets at new FA during smooth hand-off

2 MOTIVATION

Real time services require more buffers and more complex mechanisms to compensate the packet stream correctly. Packet sequence disruption during handover procedure may result in decreasing network performance especially in higher layer protocols [8]. A mobile node may cross a cell boundary during data transmission process. When initiating a handover procedure, the mobile node sends a registration request to its HA through a new FA to tell the HA about its new location. Before receiving the registration request, the HA forwards packets to the old FA of the mobile node. According to smooth handover procedure, the new FA sends binding update message to the old FA. After receiving the registration request, the HA forwards packets to the new FA of the mobile node. Packets sent to the old FA after handover will be forwarded to the new FA. If the movement of the mobile node from the old FA to the new FA happened during data transmission process, packets received at the new FA may be disordered. Figure (2) clears this situation as follows: The mobile node received packets p1, p2, and p3 from its old FA (before handover process). The mobile node changed its location (handover process) before receiving packets p4, p5, and p6 (these packets at the old FA's buffer now). The HA start forwarding packets p7, p8, and p9 to the new FA. Packets p7, p8, and p9 will be received at the mobile node (through its new FA) before packets p4, p5, and p6 which are still in the old FA's buffer . Disordered packets can cause negative ACKs and packets discarding which leads to degradation of the network performance especially in real-time transport protocol. So, real-time services should have large storage capacity to compensate the disordered packets stream. We will show that using priority scheduling for packets forwarded from old FA to new FA during handover can improve the network performance.

3 PROPOSING SOLUTION

It is clear that disordered packets are generated at the new FA when packets sent from HA after handover procedure (new packets) are received at the new FA before the packets forwarded from the old FA to the new FA (old packets) after the handover procedure. So, if we can ensure that the old packets are received at the new FA before the HA start forwarding the new packets to the new FA (i.e. to the mobile node at its new location), then there is a great chance that packets received at the new FA (after mobile node handover) will not be disordered, or at least the problem will be reduced. This decreases the network performance degradation due to this problem. From figure (2), we can conclude that the main factors affecting the disordered packets problem are:

1. Packet delay on the link between old FA and new FA
2. Packet delay on the link between HA and new FA.
3. Waiting time of old packets at the old FA.

However, the factors mentioned in 1 and 2 depend on the network architecture. In next section we will show how disordered packets problem can be reduced by decreasing the waiting time of the old packets at the old FA. This can be achieved through using priority scheduling for packets (mobile node's packets) queued at the old FA.

4 QUEUEING ANALYSIS OF PACKETS AT OLD FOREGIN AGENT

In this section we propose a mathematical model for packets queueing analysis at the old FA's buffer. In our model, there are two types of packets: normal packets (not mobile IP packets) and mobile IP packets (that should be sent to the new FA i.e. to the mobile node). The mobile IP packets will be referred to by mobile node packets (MNP). These packets will not compete with other packets (normal packets) at the old FA. Instead they will be served directly and forwarded as soon as possible to the new FA, to reach the new FA before packets forwarded from the HA to the

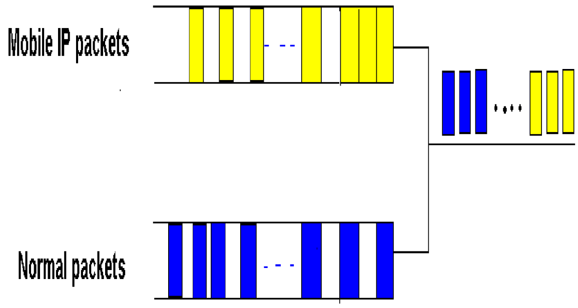

Fig. 3. Mobile IP packets are given high priority

new FA (new packets). This strategy can prevent the problem of receiving disordered packets at the new FA, or at least reduce it. In our model we will consider the following assumptions:

1. Time is divided into fixed-length intervals, referred to as slots. Nonnegative integers values $k = 0, 1, \ldots,$ are assigned to individual slot boundaries.
2. Information is divided into small, fixed-size packets.
3. The buffer has an infinite size.
4. The model can be described as a discrete-time priority queueing system with two classes of packets.
5. The system has one queue, with two classes of packets, class 1 packets are MNP and class 2 are normal packets.
6. Packets of the same class are served in FIFO service discipline.
7. MNP and normal packets arrive in batches of infinite sizes.
8. Number of MNP and normal packets arriving in consecutive slots has general distributions.
9. MNP are served before normal packets in a priority scheduling (see figure (3)).
10. Service time of MNP and normal packets has deterministic distribution.
11. The packets interarrival time has geometric distribution.

Our model can be described as batch arrivals of two classes of packets with sizes A_1 of MNP and size A_2 of normal packets. We will apply our assumptions to an $N \times N$ ATM switch with N input ports and N buffered output ports. Packets arrive at the input ports with rate r, With same chance to be routed to any output port of the switch. As a special case we consider that packets arrive at the input ports singly. So, in each slot a single MNP with rate λ or a normal packet with rate $(1-\lambda)$ arrives at each input port of the switch.

5 SYSTEM MODEL AND RESULTS

We will summarize our main results in the following:

- The joint Probability Generating Function (PGF) $A(z_1, z_2)$ of MNP and normal packets arriving at the output ports is given by

$$A(z_1, z_2) = \left(1 - \frac{r}{N} + \frac{r}{N}\left(\lambda z_1 + (1-\lambda) z_2\right)\right)^N . \quad (1)$$

- The marginal PGF $A_1(z)$ of MNP arriving at the output ports, is given by

$$A_1(z) = A(z, 1) = \left(1 - \left(\frac{r}{N}\right)\lambda + \left(\frac{r}{N}\right)\lambda z\right)^N . \quad (2)$$

- The marginal PGF $A_2(z)$ of normal packets arriving at the output ports, is given by

$$A_2(z) = A(1, z) = \left(1 - \left(\frac{r}{N}\right)(1-\lambda) + \left(\frac{r}{N}\right)(1-\lambda) z\right)^N . \quad (3)$$

- The MNP arrival rate $A_1^{'}(1)$ at the output ports, is given by

$$A_1^{'}(1) = r_1 = N\left(1 - \left(\frac{r\lambda}{N}\right) + \left(\frac{r\lambda}{N}\right) z\right)^{N-1} \left(\frac{r\lambda}{N}\right)\Bigg|_{z=1} = r\lambda. \quad (4)$$

- The normal packets arrival rate $A_2^{'}(1)$ at the output ports, is given by

$$\begin{aligned} A_2^{'}(1) &= r_2 \\ &= r(1-\lambda). \end{aligned} \quad (5)$$

- The batches arrival rate $A^{'}(1,1)$ at the output ports, is given by

$$A^{'}(1,1) = r_T = N\left(1 - \frac{r}{N} + \left(\frac{r}{N}\right) z\right)^{N-1} \left(\frac{r}{N}\right)\Bigg|_{z=1} = r. \quad (6)$$

- The second moment of the PGF $A^{''}(1,1)$ of MNP and normal packets arrivals at the output ports, is given by

$$\begin{aligned} A^{''}(1,1) &= r_{TT} \\ &= N(N-1)\left(1-\frac{r}{N}\right. \\ &+ \left.\left.\left(\frac{r}{N}\right)z\right)^{N-2}\left(\frac{r}{N}\right)^2\right|_{z=1} \\ &= r^2\left(1-\frac{1}{N}\right). \end{aligned} \quad (7)$$

- The second moment of the PGF $A_1^{''}(1)$ of MNP arrivals at the output ports, is given by

$$\begin{aligned} A_1^{''}(1) &= r_{11} \\ &= N(N-1)\left(1-\left(\frac{r\lambda}{N}\right)\right. \\ &+ \left.\left.\left(\frac{r\lambda}{N}\right)z\right)^{N-2}\left(\frac{r\lambda}{N}\right)^2\right|_{z=1} \\ &= r^2\lambda^2\left(1-\frac{1}{N}\right). \end{aligned} \quad (8)$$

- PGF of MNP occupancy is given by

$$P_1(z) = \frac{A_1(z)(1-r_1)(z-1)}{z-A_1(z)},$$

- Mean value of MNP occupancy

$$E[P_1] = \frac{2r_1 - 2r_1^2 + r_{11}}{2(1-r_1)}, \quad (9)$$

- Mean value of normal packets occupancy

$$E[P_2] = r_2 + \frac{r_{TT}}{2(1-r_T)} - \frac{r_{11}}{2(1-r_1)}, \quad (10)$$

- PGF of the queue contents and its mean value are given by

$$Q(z) = \frac{(1-r_T)(z-1)}{z-A(z)}. \quad (11)$$

$$E[Q] = \frac{r_{TT}}{2(1-r_T)}. \quad (12)$$

- In view of Little's rule, we can get the mean waiting time of MNP in the system, as follows

$$E[W_1] = \frac{E[P_1]}{r_1}, \quad (13)$$

where $r_1 = A_1^{'}(1)$. Substituting for $E[P_1]$ from (9) in (13), then

$$E[W_1] = 1 + \frac{r_{11}}{2r_1(1-r_1)},$$

- Similarly, we can proceed to derive mean waiting time of the normal packets, in the form

$$E[W_2] = 1 + \frac{r_{TT}}{2r_2(1-r_T)} - \frac{r_{11}}{2r_2(1-r_1)},$$

- Mean waiting time of an arbitrary packet in the queue is given by

$$E[W_T] = 1 + \frac{r_{TT}}{2r_T(1-r_T)}.$$

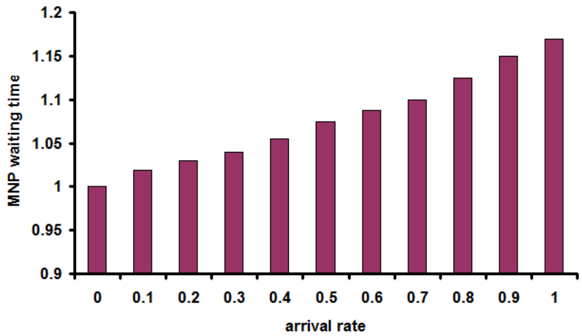

Fig. 4. MNP waiting time vs. Packets arrival rate

6 NUMERICAL EXAMPLES

Figures (4) and (5) show the relation between the waiting time of MNP and normal packets against the packets arrival rate. In both figures the waiting time of the packets is getting bigger when the packets arrival rate gets bigger. However, in figure (6) we have plotted both waiting times of MNP and normal packets against packets arrival rate in one figure. It is clear that the waiting time values of MNP are less than their corresponding values of waiting time of normal packets due to using the priority scheduling for MNP in the buffer of the old FA. So, using the priority scheduling for MNP forwarded from old FA to new FA will reduce its waiting time in the old FA. This will give chance to these packets to reach new FA in its correct time (i.e. before packets forwarded from HA to the new FA). This will forbid the problem of receiving disordered packets at the new FA or at least reduce it.

7 CONCLUSIONS

Mobile IP has gained attention as a technology that can provide mobility to universal users independently of the access network. Handover of route optimization protocol in Mobile IP results in packet sequence disruption during packet forwarding procedure. In this paper we show that using priority scheduling at the old FA can prevent (or reduce) the problem of receiving disordered packets at the

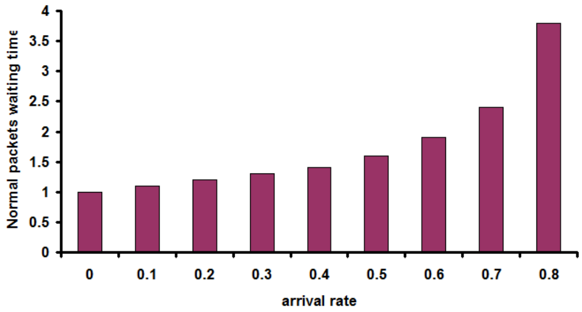

Fig. 5. Normal packets waiting time vs. packets arrival rate

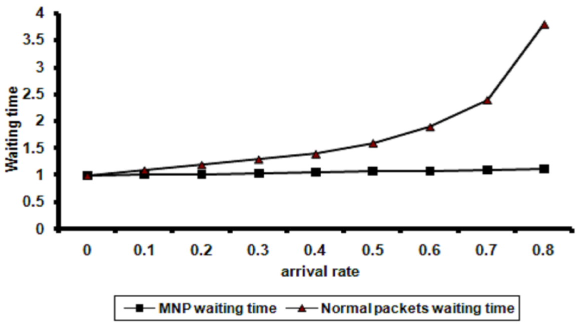

Fig. 6. Packets waiting time vs. packets arrival rate

new FA after mobile node's handover procedure from old FA to new FA. We have presented a mathematical model for the queueing analysis of the buffer at the old FA and got expressions for many of the network parameters. Our numerical results show that applying the proposed priority scheduling can improve the network performance and solve the problem of receiving disordered packets at the new FA after doing the handover.

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