ESSHP: An Enhanced Semi-Soft Handoff Protocol Based on Explicit Node Decision in Cellular Networks*

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Abstract. Due to frequent handoff, Mobile IP has been confronted with some limitations. Cellular IP, one of micro-mobility protocols, was proposed to overcome these limitations and to provide good handoff performance. However, some drawbacks of Cellular IP like packet loss have been addressed. We propose an enhanced semi-soft handoff protocol based on a node's decision to cope with these drawbacks. With a bi-casting mechanism based on an explicit node decision, the proposed protocol can achieve fast and seamless handoff.

1 Introduction

Mobile IP [1] designed to support host mobility has been faced with some limitations – packet loss and high control overhead - due to frequent handoff. To cope with these limitations, micro-mobility protocols such as Cellular IP [2] and HAWAII [3] have been proposed. Especially, Cellular IP [2] has shown good performance despite of frequent handoff. Cellular IP has been designed to support seamless mobility and fast handoff. It uses the mobile routing mechanism instead of the tunneling mechanism so that it has shown better performance than hierarchical Mobile IP-based protocols [4].

However, some drawbacks of the bi-casting scheme for semi-soft handoff - packet loss and duplication - in Cellular IP have been addressed by [2][5][6]. These problems are caused by inconsistence of hop counts and amount of traffic between two paths – one between a crossover node and an old BS and the other between a crossover node and a new BS. To solve them, one approach [5] tries to calculate accurate delay time, and another approach [6] uses an indication message. These approaches still have limitations such as difficulty to measure delay and occurrence of packet duplication due to frequent changes of network conditions. Therefore, we propose an Enhanced Semi-Soft Handoff Protocol (ESSHP), which can overcome these problems.

The proposed semi-soft handoff protocol has aimed at seamless handoff without packet loss and duplication. This handoff scheme improves the semi-soft handoff

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mechanism in Cellular IP, using a mobile node's decision. Thereby, the proposed protocol can ensure fast and seamless handoff without packet loss and duplication.

The rest of this paper is organized as follows: In Section 2, we present the overview and features of ESSHP. In Section 3, we compare ESSHP with Cellular IP through simulation results. Finally, in Section 4, we conclude this paper.

2 Enhanced Semi-Soft Handoff Protocol (ESSHP)

The proposed semi-soft handoff protocol builds on a mobile node's decision and the fast handoff mechanism [7]. To protect packet loss and duplication, ESSHP depends on the decision of a mobile node because only a mobile node surely knows which packet it should receive. Basically, ESSHP handoff operations are based on the fast handoff mechanism, but we have modified some parts to eliminate unnecessary messages related to tunnels, to support the proposed bi-casting mechanism, and to reflect the decision of a mobile node.

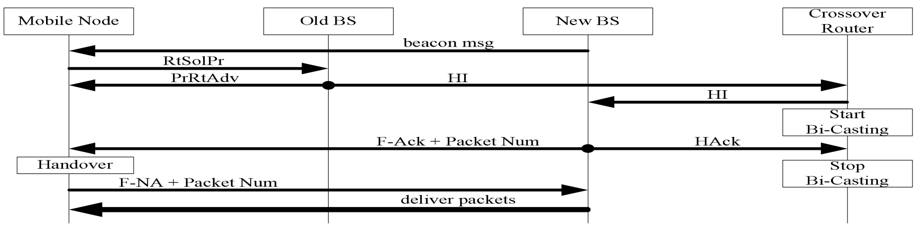

Fig. 1. Handoff Procedure of ESSHP

The handoff procedure of ESSHP is shown in Fig 1. When a mobile node starts handoff, it sends a Router Solicitation for Proxy (RtSolPr) message to inform an old BS with the information of a new BS. While the old BS replies a Proxy Router Advertisement (PtRtAdv) message to the mobile node, it sends a Handover Initiate (HI) message to the new BS via a crossover router. When the crossover router receives a HI message, it starts bi-casting. The new BS sends a Fast Acknowledgement (F-Ack) message to the mobile node to notify that it is ready to send packets. This F-Ack message includes useful information - *the first packet number* - to help the mobile node's decision. Also, it replies a Handover Acknowledgement (HAck) message to stop bi-casting. With the F-Ack message, the mobile node determines whether it attaches the new BS. If *the received packet number* which the mobile node has been received from the old BS is smaller than *the first packet number* from the new BS, it continues to receive packets from the old BS utile *the received packet number* is the same as *the first packet number - 1*. If *the received packet number* is bigger, it immediately attaches the new BS and transmits a Fast Neighbor Advertisement (F-NA) with its decision - *the next packet number* which it wants to receive. If *the next packet number* is bigger than the packets which the new BS has, the new BS waits for the packets which the mobile node requests. If *the next packet number* is smaller than the packets which the new BS contains, the new BS drops all packets prior to *the next packet number*. Thereby, ESSHP can provide seamless handoff without packet loss and duplication.

3 Performance Evaluation

We have experimented with NS-2 simulator [8] to examine the amount of packet loss and duplication and to measure TCP performance. Before showing simulation results, we describe three kinds of situations based on packet delivery time.

Table 1. Two Kinds of Packet Delivery Time

Notation	Definition
$T_{CR\text{->}OBS}$	Packet delivery time from a crossover node to an old BS
$T_{CR\text{->}NBS}$	Packet delivery time form a crossover node to a new BS

- $T_{CR\text{->}OBS} = T_{CR\text{->}NBS}$
  This case means that bi-cast packets arrive at an old BS and a new BS simultaneously, so there is no packet loss and duplication in both Cellular IP and ESSHP
- $T_{CR\text{->}OBS} > T_{CR\text{->}NBS}$
  In another case that bi-cast packets destined to a new BS arrive faster than an old BS, packet loss occurs in Cellular IP. On the other hand, there is no packet loss in ESSHP because a new BS stores these bi-cast packets in its buffer. It transmits these packets when a mobile node requests.
- $T_{CR\text{->}OBS} < T_{CR\text{->}NBS}$
  In the other case that bi-cast packets destined to an old BS arrive faster than a new BS, packet duplication occurs in Cellular IP. However, there is no packet duplication in ESSHP because a new BS drops all duplicated packets which a mobile node already receives from an old BS.

Fig2 (a) and (b) illustrate examples of packet loss and duplication in Cellular IP, and Fig2 (c) and (d) present examples of no packet loss and duplication in ESSHP.

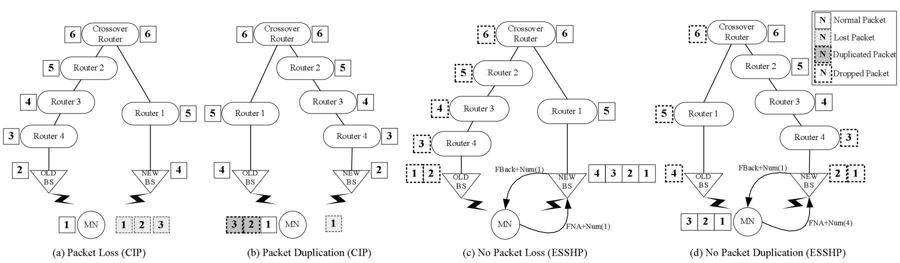

Fig. 2. Comparison of Cellular IP and ESSHP

To examine the performance of ESSHP and Cellular IP, we have implemented the proposed handoff protocol using the ns-2 simulator [8] and Cellular IP based on [9].

According to the first simulation results described in Fig 3 (a) and (b), amount of packet loss and duplication rises rapidly in Cellular IP as the gap between two distances increases. However, packet loss and duplication do not happen in ESSHP regardless of the increase of the gap. In TCP performance shown in Fig 3 (c) and (d), as the gap between two paths becomes bigger, the performance of Cellular IP becomes worse whereas that of ESSHP is not affected by the gap. In Cellular IP, the slow start mechanism is triggered by packet loss during handoff so that TCP throughput is degraded sharply. On the other hand, ESSHP shows stable TCP performance even though the gap increases. Based on the results of these experiments, it is obvious that ESSHP can provide seamless handoff without packet loss and duplication.

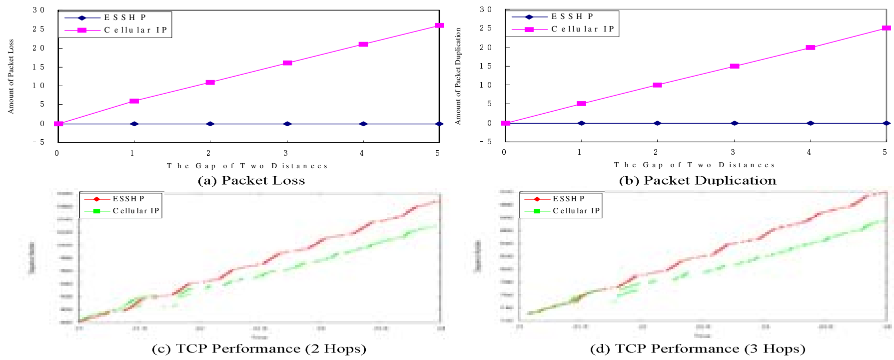

Fig. 3. Simulation Results

4 Conclusions

In this paper, we present an enhanced semi-soft handoff protocol which improves Cellular IP. To provide seamless and fast handoff, ESSHP depends on the fast handoff mechanism [7] and the decision of a mobile node which is helpful information for handoff. Especially, the decision of a mobile node assists to prevent occurrence of packet loss and duplication. With these features, we can insist that ESSHP be a suitable micro-mobility protocol in cellular network environment.

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