



Original article

# Optimizing Packet Loss in Mobile IP Wireless Network Handover Performance Using Particle Swarm Optimization: The Role of Overlap Area Effectiveness

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## Abstract

The rapid development of wireless technologies has led to a shift towards total mobility. Mobile IP provides mobility to mobile users and terminals as they change their point of attachment during handovers from a previous wireless access network to a new access network. This mobility is managed within the network layer through Mobile IP extensions, where mobile connectivity is supported while the MN is roaming between different wireless access networks. However, there are still several technical barriers, such as long handover periods and packet loss, that need to be overcome before the wide deployment of the Mobile Internet. In applications involving real-time traffic in IP wireless networks, mobile IP provides reliable access to the Internet. Mobile IP, is a network layer routing protocol, which was designed by the IETF (Internet Engineering Task Force) to provide solutions to the requirements of mobile computing. However, there are still many technical obstacles that must be overcome before Mobile IP can be widely deployed. Moreover, since mobility performance is the outcome of the cooperation of different layers, merely focusing on the network layer performance is not sufficient. In other words, the operation of Mobile IP depends heavily on lower-layer mechanisms and has direct implications for upper-layer performance. Therefore, in this paper, we optimize the number of packets lost based on the overlap area width in Mobile IP handover using Particle Swarm Optimization (PSO). Avoid losses of information during handover in Mobile IP networks. In this paper, we optimized the performance of the system using the PSO algorithm to improve the overall IP mobility performance. This paper focuses on the network handover mobility protocols and proposes enhancements to Mobile IP. The optimization schemes using MATLAB on the PSO Algorithm. Therefore, cross-layer analysis and design are necessary to improve the overall IP mobility performance. This paper focuses on the network layer mobility, proposes enhancements to Mobile IP, analyzes the impact that link layer mechanisms cause to IP mobility performance, and examines the implications of IP mobility on the transport layer, and concerns about the packet loss of information during handover. These occur during the movement from one point to another to achieve seamless mobile computing in a heterogeneous wireless access environment.

**Keywords:** MATLAB on PSO Algorithm, Network Layer Mobility, IP Mobility Performance, Handover in Mobile IP.

## Introduction

Internet technology is widespread throughout the world, offering access to a variety of information and resources. Traditionally, however, the service is only available when people settle down in their offices, homes, or any other authorized areas, typically by plugging a physical jack into a wall. Although the development of wireless communication technologies has made wireless Internet access possible and more and more portable devices, such as PDAs (Personal Digital Assistants), digital cellular phones, and laptop computers, and so on, provide Internet access functionality, it does not mean that Internet communication activities can remain uninterrupted while users are moving. Mobile computing and portable computing are two different concepts. If mobile users only need to be able to launch communication sessions actively before other network nodes can communicate with them when they are roaming, and do not mind reestablishing sessions every time they change their access link, portable computing is sufficient to offer the service. However, mobile computing provides mobile users with anytime, anywhere, bidirectional, reliable access, and that includes the requirement that ongoing communication sessions do not need to be restarted even when the point of attachment to the Internet changes.

Since the *Internet Protocol* (IP), the core protocol of the Internet, was originally designed for fixed networks, IP addresses are associated with a fixed network location, and they are required to remain unchanged during an IP session. Obviously, this is unable to satisfy the requirements of mobile computing. Therefore, Mobile IP [1] [2] was proposed by the IETF (Internet Engineering Task Force) to offer mobile users a seamless computing environment.

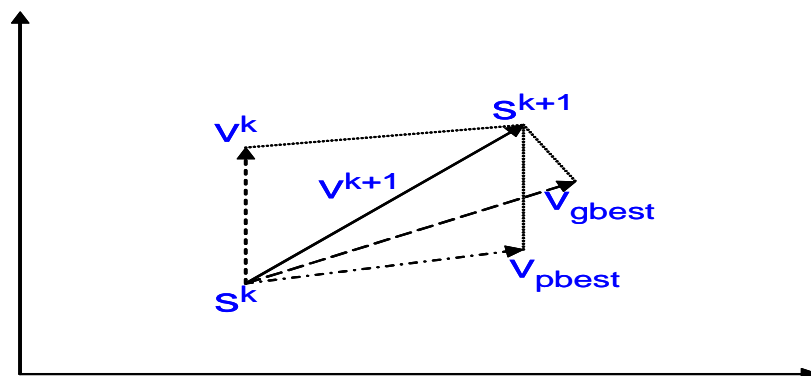
Mobile computing offers mobile users anytime, anywhere, bi-directional, reliable access to the Internet. Mobile IP, as a network layer routing protocol, was designed by the IETF (Internet Engineering Task Force) to provide solutions to the requirements of mobile computing. Many technical obstacles must be overcome before Mobile IP can be widely deployed. Moreover, since mobility performance is the outcome of the

cooperation of different layers, merely focusing on the network layer performance is not sufficient. In other words, the operation of Mobile IP depends heavily on lower-layer mechanisms and has direct implications on upper-layer performance. Space that adjusts its “flying” according to its own flying experience as well as the flying experience of others. Therefore, Optimization of packet losses in wireless network design is necessary to improve the overall IP mobility performance. In this paper, we optimize the packet losses using the PSO Algorithm based on the overlap area width. PSO is a robust stochastic optimization technique based on the movement and intelligence of swarms. It uses several agents (particles) that constitute a swarm moving around in the search space, looking for the best solution. Each particle is treated as a point in an N-dimensional space of other particles.

Loss of information in any case is not acceptable. In a mobile IP network, a change in the network or a change in location and point of attachment is one of the main causes of loss of information. However, mobile computing provides mobile users with anytime, anywhere, bidirectional, reliable access, and that includes the requirement that ongoing communication sessions do not need to be restarted even when the point of attachment to the Internet changes. Optimization of packet losses using PSO schemes to achieve seamless handover in mobile computing in a heterogeneous wireless access environment. Mobile computing and portable computing are two different concepts. If mobile users only need to be able to launch communication sessions actively before other network nodes can communicate with them when they are roaming, and do not mind reestablishing sessions every time they change their access link, portable computing is sufficient to offer the service.

### Research contribution

Analyzing Mobile IP handover and enhancing handover performance are among the main objectives of this paper. First, an outline of handover problems and enhancements is given. So far, some key factors affecting Mobile IP handover performance have been examined. Note that the simulation results presented may be perfectly precise because, despite being randomly generated, link delays. However, the calculations provided have proven the validity of the simulations. The larger the overlap area is, the smoother a handover could be; however, the more severe the signal interference could be. The larger the effective overlap area is, the higher the speed of the MN accommodated. The shorter the Agent Advertisement interval is, the smoother a handover could be. However, in practice, the wireless bandwidth consumed may in turn cause performance degradation. The longer the data packet interval, the fewer the packets lost during a handover. The heavier the network traffic loads are (the longer the link delays are), the worse the handover performance will be.



**Figure 1. Concept of modification of a searching point by PSO**

$s_k$ : current searching point.

$s_{k+1}$ : modified searching point.

$v_k$ : current velocity.

$v_{k+1}$ : modified velocity.

$v_{pbest}$ : velocity based on  $pbest$ .

$v_{gbest}$ : velocity based on  $gbest$

Each particle tries to modify its position using the following information:

The current positions,

The current velocities,

The distance between the current position and  $pbest$ ,

The distance between the current position and the  $gbest$ .

The modification of the particle's position is mathematically modeled according to the following equation

$$V_{k+1} = wV_k + c_1 \text{rand1}(\dots) \times (pbest_i - s_{ik}) + c_2 \text{rand2}(\dots) \times (gbest - s_{ik}) \dots \dots \dots (1)$$

Where,

$v_{ik}$ : velocity of agent  $i$  at iteration  $k$ ,  
 $w$ : weighting function,  
 $c_j$ : weighting factor,  
 $rand$ : uniformly distributed random number between 0 and 1,  
 $s_{ik}$ : current position of agent  $i$  at iteration  $k$ ,  
 $p_{best_i}$ : pbest of agent  $i$ ,  
 $g_{best}$ : gbest of the group.

The following weighting function usually utilized in (1)

$$w = w_{Max} - [(w_{Max} - w_{Min}) \times iter] / maxIter \dots \dots \dots (2)$$

Where:

$w_{Max}$  = initial weight,

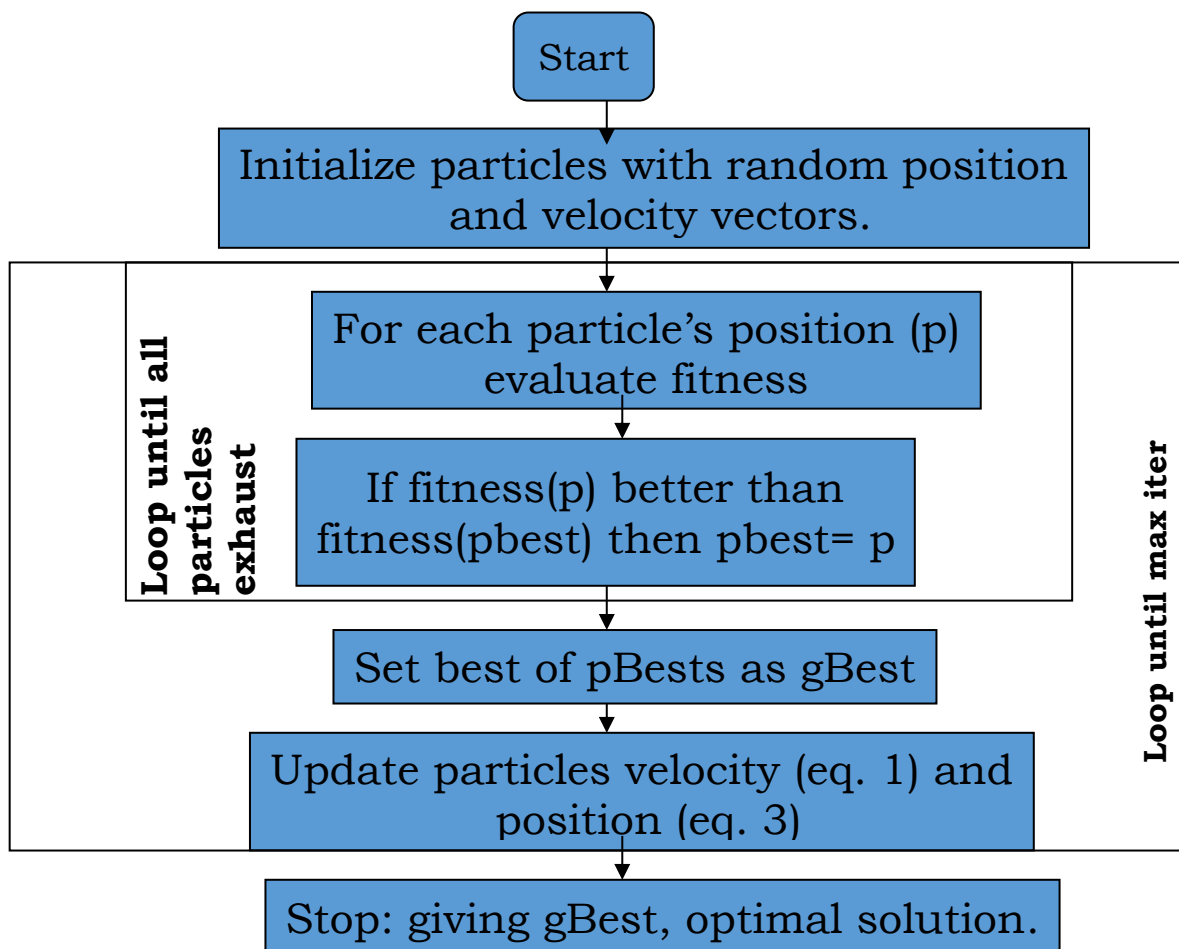
$w_{Min}$  = final weight,

$maxIter$  = maximum iteration number,

$iter$  = current iteration number.

$$s_{ik+1} = s_{ik} + V_{ik+1} \dots \dots \dots (2)$$

#### 4 Flow chart depicting the General PSO Algorithm.



**Figure 2. General PSO Algorithms**

#### Result Analyses and Optimization

The number of lost packets, handover latency, usually judges Mobile IP handover performance, and the amount of network resource (i.e., bandwidth, buffer, and so on) needed. In this section, each simulation scenario and its results are presented.

##### **Number of Lost Packets - Overlap Area Width**

The size of the overlap area between two FAs is one of the key factors that affect the performance of a handover, since it directly affects the length of the rendezvous time.

Both in theory and from simulation, the handover effect (the number of lost packets) is studied with different settings of the overlap area width between every two FAs. The MN performs 12 intra-domain handovers and 4 inter-domain handovers without any handover-enhancing techniques in this scenario.

Note that since the MN is moving around the circle shown in (Figure 3), the actual length of the path it passes in an overlap area is slightly longer than the maximum overlap width. Their difference (*diff*) is given

$$diff = R\phi - 2R\sin\left(\frac{\phi}{2}\right) \dots\dots\dots (3)$$

For  $\phi = \frac{\pi}{8}$ ,  $diff = 0.0025R \dots\dots\dots (4)$

Therefore, this difference ignored in later analyses. Before analyzing (Figure 5.1) in detail, the concept of “effective overlap width”. Since there are three power thresholds for the receive signal set in the simulations, three corresponding radii (*rth1*, *rth2*, and *r*) are obtained. While the MN is moving from FA1 to FA2, only when it is between point A and point B, is it able to accept Agent Advertisements from FA2. Thus, the distance between A and B (*d*) had called the effective overlap width. Given the distance between two FAs *D*, there is  $d = rth1 - (D - r)$ ,  $d \leq (r - rth2)$ .  $\dots\dots\dots (5)$

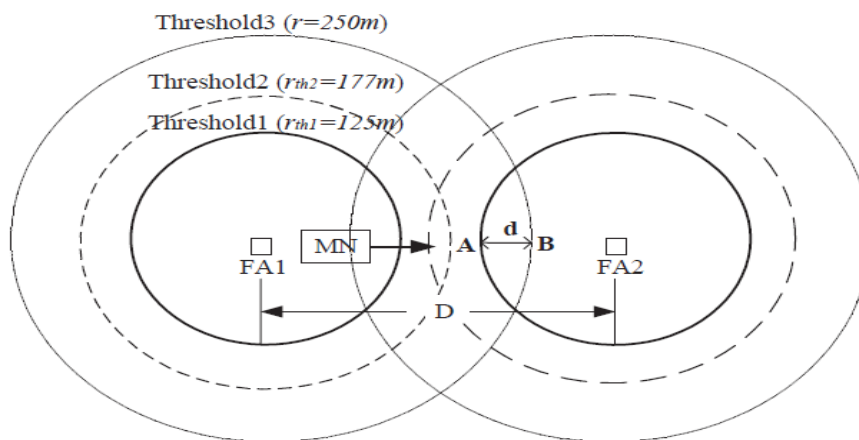
Which can concluded, when the value of the overlap area width is between 0 *m* and 125 *m*, the number of packets lost decreases linearly; whenever the value of the overlap area width is between 125 *m* and 140 *m*, the number of packets lost decreases non-linearly; and finally when the value of the overlap area width is larger than 145 *m*, the number of packets lost remains constant.

The phenomenon is explained by some calculations. Firstly, the lost packets are divided into three types based on their lost period:

Packets lost (with mean value *L1*) during the period (with mean value *T1*) that elapses between the moment the MN loses contact with FA1 and the moment the MN enters the *rth1* of FA2. Note that only when the effective overlap width *d* > 0 calculated from Eq. (4), is there *T1* = 0 and therefore *L1* = 0.

Packets lost (with mean value *L2*) during the period (with mean value *T2*) that elapses between the moment the MN enters the *rth1* of FA2 and loses contact with FA1, and the moment the MN gets an Agent Advertisement. Note that only when it takes a time longer than the Agent Advertisement interval for the MN to travel through the effective overlap width *d*, is there *T2* = 0 and therefore *L2* = 0.

Packets lost (with mean value *L3* in home registrations and *L'3* in regional registrations) during the period (with mean value *T3* for home registrations and *T'3* for regional registrations) that elapses between the moment the MN sends a Registration Request and the moment the MN receives a Registration Reply.



**Figure 3. Effective Overlap Width**

Thus, the overall number (*L*) of packets lost during the simulations is given by

$$L = 16 \times (L1 + L2) + 4 \times L3 + 12 \times L'3 \dots\dots\dots (6)$$

Assuming the overlap area width is *O*, there is

$$D = 2r - O, O \geq 0 \dots\dots\dots (7)$$

When 0 *m* ≤ *O* < 125 *m*, it can be deduced that *d* < 0, and therefore

$$T1 = \frac{d}{v} \dots\dots\dots (8)$$

$$L1 = \frac{T1}{i} \dots\dots\dots (9)$$

Where *v* and *i* are the speed of the MN (20 *m/s*) and the packet interval (0.02 *s*), respectively. However, *L2*, *L3*, and *L'3* remain constant. As a result, the number of packets lost (*L*) decreases linearly, since *T1* and *L1* decrease linearly as *O* increases at this stage.

When 125 *m* ≤ *O* < 145 *m*, then 0 *m* ≤ *d* < 20 *m* (according to Eq. (9) and (8)), *T1* = 0, and *L1* = 0. Moreover, *L3* and *L'3* remain constant. However,

$$T2 = \left(1 - \frac{d}{v}\right) \left[\left(1 - \frac{d}{v}\right) \times \frac{1}{2}\right] \dots\dots\dots (10)$$

Therefore  $T2 = \frac{1}{2} \left(1 - \frac{d}{v}\right) \dots\dots\dots (11)$

$$L2 = \frac{1}{2i} \left(1 - \frac{d}{v}\right)^2 \dots\dots\dots(12)$$

As a result, according to Eq. (12) and (10), the number of packets lost (*L*) decreases.

When  $O > 145\text{ m}$ , it can be obtained by Eq. (12) and (10) that  $d \geq 20\text{ m}$ .

In this case, since the MN needs a time longer than the Agent Advertisement interval to travel through the distance given by *d*, only  $T_3$  and  $T'_3$  are non-zero, and they remain constant. As a result,  $L_3$ ,  $L'_3$ , and therefore *L* do not change in this region.

(Figure 3) shows that the simulation results accord with the theoretical analysis in general. Some points slightly depart from the theoretical results because of the randomly generated link delays.

**Cost Function**

$$F(\text{rth1}) = \left| 1 - \left( \left( \frac{16}{2 \cdot i} \right) * \left( 1 - (\text{rth1} - (D - r)/v^2) / L \right) \right) \right| \dots\dots\dots(13)$$

*i* = Packet interval

*L* = Number of packets Lost

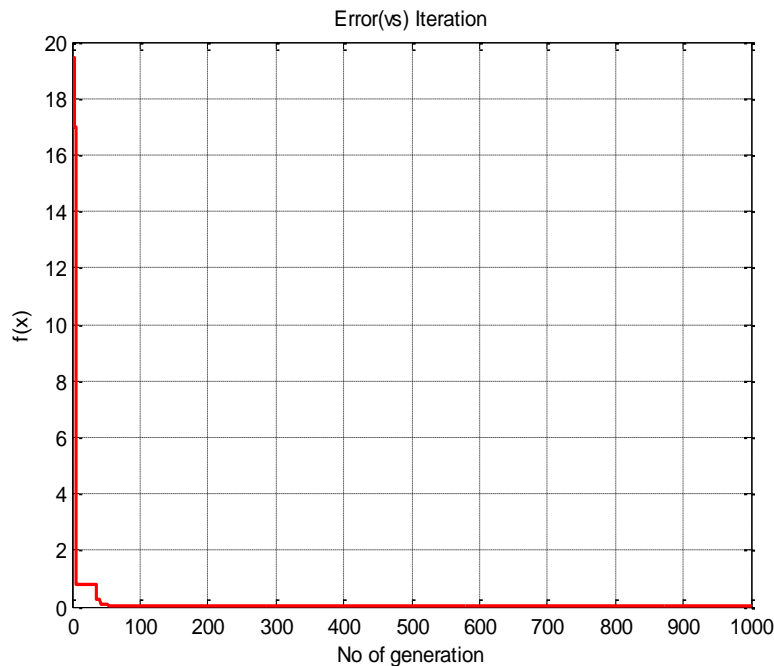
*v* = Mobile node speed, *rth1* = Overlap Area width

**Table 1. Optimized Number of Packets Lost vs. Overlap Area Width using PSO**

Theoretical value of Overlap Area Width (rth1 in Meter)	Optimized Overlap Area Width(rth1) from PSO (In Meter)	Number of Packets Lost (In Byte)
0	0.0028	15626
20	20.0055	11025
40	39.999	7225
60	60.000	4225
80	80.179	2025
100	100.000	625
120	119.080	25
140	140.069	225

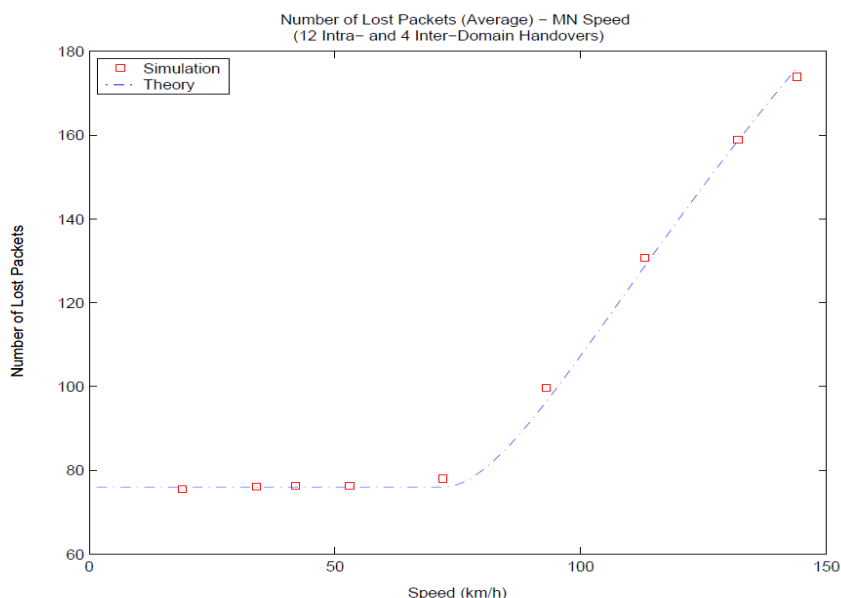
As shown in (Table 1), there are two types of values of overlap area width found: one is the theoretical value, and the other is the optimized value from the PSO algorithm.

**Result Optimization**



**Figure 4. Optimization graph**

(Figure 5) shows the optimization of the function  $f(x)$  Eq. (13) over 100 iterations. The graph shows the best fitness result.



**Figure 5. Number of Lost Packets-Overlap Area Width (Optimized Using PSO)**

## Conclusion

This paper examines Internet mobility performance across the link, network, and transport layers, with particular emphasis on the interactions between these layers. At the network layer, the focus is on Mobile IPv4 (MIPv4) as the foundation of Internet mobility support. The protocol's mechanisms described along with its key challenges, including handover disruption, triangle routing, and security issues. Existing enhancements such as macro- and micro-mobility concepts, regional registration, smooth and fast handovers, route optimization, and dynamic key distribution outlined. Through simulations, tunnel-based and multicast-based handover optimization algorithms compared, highlighting their respective strengths and weaknesses. Factors influencing IP layer handover performance—packet loss, disruption time, and buffer consumption included analyzed. To address registration delays, a Packet-Differentiated scheme proposed to accelerate signaling in hierarchical Mobile IP without compromising security. Additionally, a Two-Way Registration scheme introduced to improve inter-domain (macro-mobility) handovers, with simulations confirming its effectiveness. At the transport layer, the study considered TCP congestion control mechanisms and the impact of mobility on performance, including packet loss, delay, reordering, bursts, and bandwidth-delay mismatches. Existing solutions reviewed, with particular attention to challenges arising during vertical handovers.

**Conflict of interest.** Nil

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