Performance Studies of Layered MIPv6 based Network Architecture for better QoS: a Mathematical Approach

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Summary
Layered architecture is considered as a suitable solution for seamless mobility for Mobile IPv6 based network in terms of handoff latency. But too many layers in the hierarchy introduce large amount of packet drop at the anchor agents and degrade the efficiency of anchor agents. So, determining the optimal layers of hierarchy for better QoS parameters such as handoff latency, packet loss and overall efficiency is a challenging research area. The work presented in this paper is a mathematical analysis of a general n-layered architecture to find optimal levels of hierarchy with minimum handoff latency and packet dropping probability along with a measure of efficiency of anchor agents at different layers. The factors that affect the performance of the hierarchical model are the number of mobile nodes under an anchor agent and packet arrival rate at the agent. We assume that each of the anchor agents in the network maintains an M/M/1/K queue and the packet arrival rate at the anchor agent follows Poisson's distribution. Analysis shows that handoff latency decreases by a ratio of 25-35% with the addition of a new layer up to layer three, around 15% decrease on adding fourth layer and a negligible decrease of 2-3% beyond layer four. Also, packet-dropping probability is directly proportional to the offered load, which in turn is dependent on the number of mobile nodes. As the number of layer increases, the coverage area of the anchor agent as well as the mobile nodes under its coverage increases. A 2-5% of the packets are dropped up to layer four beyond which it exceeds 5%. A 5% handoff dropping is not considered to be acceptable. Also, the efficiency of anchor agent remains above 97% up to layer three for most of the packet arrival patterns and MN density. So, considering the performance parameters such as handoff latency, packet dropping probability and efficiency of anchor agent, a three-layered architecture may be considered optimal.

Key words :
MIPv6, QoS, Mathematical Approach

1. Introduction

Worldwide acceptance of network architecture for seamless mobility is characterized by many parameters. Handoff latency is the most vital out of all these. The handoff latency is measured as the duration of time to reestablish the connection by a mobile node (MN) with its correspondent node (CN) during change over of one point-of-attachment to another [1]. Since from the time the MN is detached from the old point-of-attachment till the reestablishment of connection with the new point-of-attachment, MN can neither receive nor send data to its CN(s). Thus the network drops all the packets destined to MN during the handoff period. Hence, least possible handoff latency is a desirable requirement for seamless mobility. To minimize handoff latency various methods have been adopted so far. Mobile IPv4 [1] suggests that all mobile nodes initially register with a Home Agent (HA) as well as with a Foreign Agent (FA) [1] when they visit a foreign network. Agents keep track of current position and status of any MN, are introduced to minimize the handoff latency by finding the location of the MN during its movement. The concept of agent is also borrowed to Mobile IPv6 (MIPv6) [2] but the new agent called Access Router (AR) is introduced by substituting FA of MIPv4. Hierarchical MIPv6 (HMIPv6) [2,15] adds another agent called Mobile Anchor Point (MAP) to make the micro mobility of MNs transparent to the HA and CNs. Introduction of MAP significantly reduces the handoff latency as compared to MIPv4. The concept of layered architecture for seamless mobility is primarily based on the concept of hierarchical arrangement of anchor agents so that handoff latency could be sufficiently reduced [3,4,5]. Such an agent provides care-of-address (CoA) to visitor mobile node (MN) and informs home network through binding registration (BR) process through exchange of Binding Update (BU) and Binding Acknowledgement (BACK) messages [5]. MN may change its current CoA during its residency in the foreign network. In such cases, MN needs to update its new CoA to home network. This process is called binding update process and involves BU/BACK exchange. The time taken to complete the binding update process is called handoff latency. During this period, all packets destined to the MN are dropped. Higher the handoff latency more will be the

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packet loss. Again, when users are highly mobile and large number of ongoing sessions is associated, a large number of BU/BACK messages as well as data packets are transmitted. In such conditions, either BU/BACK messages or data packets may be dropped at the anchor agent. Dropping of handoff related message increases handoff latency or may disconnect the on-going communication. Dropping of data packets may lead to unacceptable quality of service to end-users. Users are more sensitive to disruption of ongoing communication rather than blocking it during connection establishment. As the anchor agent coordinates the handoff process as well as conversation between MN and CN(s), and also anchor agents are shared by number of MNs, so the resources of the anchor agents must be utilized efficiently. Hence, the mathematical analysis of the efficiency of any anchor agent may help to improve the performance of the hierarchical architecture. To provide an acceptable QoS, network architecture must support minimum handoff latency and packet dropping probability. There are architectures with one or more hierarchies proposed to minimize handoff latencies. In this paper, we have analyzed the handoff latency and packet dropping probability at anchor agents in a general *n*-layered MIPv6 based network. Through mathematical evaluation, the aim of this work is to find out the optimal layers of hierarchy in terms of handoff latency and packet dropping probability at different anchor agents along with the efficiency measurement of these anchor agents. In mobile environment packets are dropped by the network due to two reasons; during the handoff when the MN's location is not known and due to congestion in the network. The packet dropping probability that is discussed here is due to packets dropped at the anchor agents in different levels of the hierarchy when congestion occurs in the network. In such congested networks, initially the packets are queued in the anchor agent and when queue is full, packets are dropped. The following assumptions are made in accordance to mathematical analysis of the above mentioned issues:

- Anchor agents are arranged as tree and M/M/1/K queue is maintained at each of the anchor agent.
- Packet arrival process at any anchor agent obeys Poisson's distribution.

To find the optimal level of hierarchy for better handoff latency, lower packet drop and efficient use of anchor agents, this paper has contributed by

- Analyzing the handoff latency for a general *n*-layered architecture for different speeds of MN.
- Analyzing the packet dropping probability at various anchor agents so that an acceptable QoS under different packet arrival rate and MN speed can be provided to end-users.
- Measuring the efficiency of anchor agents at different levels, it is to find up to what level of hierarchy resources at anchor agent could be used efficiently.

Rest of the paper is organized as follows. A survey of related work in mobile IP based network is discussed in section 2. Section 3, presents our motivation towards this work. A brief description of proposed multilevel HMIPv6 architecture [3,14] is found in section 4. Section 5 explains the mathematical background in support of the analysis made in this paper. Performance analysis of our model is done in section 6. Finally, section 7 concludes the paper.

2. Survey of Related Work

The first protocol for mobility management in IP based network is Mobile IPv4 [1]. MIPv4 suffers from lack of route optimization as well as shortage of address space. Due to lack of route optimization it suffers high handoff latency. MIPv6 [4, 2] is the enhancement of mobility management in IPv6, and resolves the problem of address space shortage that exists in IPv4 and provides the route optimization. In MIPv6 the care of address (CoA) assigned to a MN in its visited network is reported to the HA as well as to the Correspondent Node (CN). So, it reduces end-to-end delay significantly by sending packets directly to MN from CN without the intervention of HA. MIPv6 also reduces handoff latency as compared to MIPv4. But, MIPv6 overwhelm both the local and backbone network when MN moves very fast and also handoff delay is not sufficiently small to cope up with the packet loss before the end-to-end path establishment in the new AR [4]. To further reduce the handoff latency, specifically for the MNs that move in a confined area such as within a building or in a campus, Hierarchical Mobile IPv6 (HMIPv6) [2] introduces the concept of local and global mobility and divides the entire network into two parts known as backbone and local domain. A Mobile Anchor Point (MAP) at the boundary of the local domain in HMIPv6 minimizes the signaling cost over the backbone network by making MN's mobility transparent to the HA and CNs [2]. But HMIPv6 does not perform well for globally moving MNs. The work carried out in [17,18,19,20] are few of the research in the recent past that deals with handover and mobility management in layered architecture for mobile IPv6 in general and HMIPv6 in particular. In paper [16] a novel approach for mobility management in HMIPv6 is suggested. Work of [17] is a method to improve handoff latency of MIPv6 in wireless environment. The proposal made in [18] is a description of binding update during handoff in HMIPv6 under the influence of network mobility (NEMO) protocol (RFC 3963). A two layered architecture to support fast handover in MIPv6 based network in presence of Session Initiation Protocol (SIP) is given in [19]. A distributed mobility management scheme for HMIPv6 is the matter of discussion in [20].

To provide higher degree of scalability and handle both slow and fast moving MNs efficiently, there is always a tendency to organize a group of anchor agents in the local domain by placing them in different levels either as a pyramid [6] or as a tree [5]. Although hierarchical arrangement of anchor agents minimize the signaling overhead in one hand but increases the tunneling cost and cost of binding refresh on the other. In section 3, we briefly discuss few of them along with their pitfalls, which have motivated the work presented in this paper.

3. Motivation and Objective

In performance evaluation and design of wireless mobile networks, call dropping probability, handoff probability, handoff rate, and the actual call holding times are very important performance parameters [7]. Work presented in [7] derives analytical formulae for these parameters using a novel unifying analytical approach. In most of the analysis of wireless network, involved time variable is modeled as a probabilistic function with exponential assumptions. But in [7], involved time parameter uses probability with linear assumptions. Again, the cell residence time on MN is assumed to be independent and not influenced by residence time in earlier cell or other MN in the same cell. It has shown that such assumptions can represent computational aspect of many performance parameters in an efficient and effective way. The analytical results obtained can be easily applied when the Laplace transform of probability density function of call holding time is used. When the call holding time is distributed with the mixed-Erlang distribution, computation becomes easy. This paper develops a new analytical approach to performance evaluation for wireless networks and mobile computing systems. The paper [4,16] models HMIPv6 with an M/M/1/K queue at the anchor agent. The authors also analyzed the network cost and bandwidth consumption of delivering management messages and data payload in both inside and outside the hierarchical domain. They have proposed a mathematical model of HMIPv6 with the consideration of queuing model in the anchor agent and built an intelligent system called Intelligent Mobility Management Scheme (IMMS), which allows an MN to select a suitable mobility management mechanism from MIPv6 and HMIPv6 according to its working parameters. The work of [8] discusses the blocking probability at MAP in HMIPv6. They have compared the performance of Robust Hierarchical-MIPv6 (RH-MIPv6) and HMIPv6 taking the probability of MAP unavailability as one of the factors. They have also assumed an M/M/C/C queue at the MAP. References [3, 4, 7, 8] are about single layer architecture and analyze signaling overhead, tunneling cost, or handoff latency. Despite its significance, packet-dropping probability and efficiency analysis of anchor agents are not discussed in these papers. In our paper, we consider the issues of packet dropping probability and efficiency for mobile IP based network. Our intention is to investigate and analyze packet-dropping probability at each of the anchor agents and efficiency of anchor agents in *n-layer* architecture, along with the handoff latency. This work is based on the mathematical model [3] for general *n*-layered MIPv6 architecture for wireless IP-based network. Mathematical analysis shows that the packet dropping probability is directly proportional to the offered load in the anchor agents which is dependent on the number of mobile nodes. The number of mobile nodes under any anchor agent increases as we increase the number of layers. Similarly, efficiency of anchor agents falls below *90%* for most of the packet arrival rate (section 6) and it goes down rapidly beyond layer four or higher. That is why, although handoff latency decreases with the increase of layers, increasing the number of layers to a higher degree is neither beneficial nor acceptable. Keeping in mind these facts, we try to establish an optimum level of hierarchy for future distributed network architecture with varied mobility of users through mathematical analysis. The aim is to get optimum values for both handoff latency and packet dropping probability and optimal utilization of anchor agents.

4. Proposed Network Architecture

Our proposed *n-layered* architecture is shown in Figure 1. The network components and their functions as listed below:

MAP**:** Mobile Anchor Points (MAP) are agents that makes the mobility of the nodes inside a micro-mobility domain transparent to the HA and CNs. They are organized hierarchically in the micro mobility domain. The lowest level MAPs are called L1-MAP; next level is called L2-MAP and so on. We assume that there may be *n* number of layers in the hierarchy. Each of the higher-level MAP covers a group of MAPs under it. The top level contains single MAP called Global MAP (GMAP) and communicates directly with HA and CN. This arrangement of MAPs leads to a tree like structure.

AR: A mobile node (MN) registers with an Access Router (AR) when it visits a foreign network. The AR provides a Link Care of Address (LCoA) to the visited MN and also supplies a group of CoA depending upon the level of hierarchies that a MN needs to update.

MN: A host that changes its point of attachment from one network to another without changing its IP address. It acquires local care of address (LCoA) and CoAs from its servicing AR.

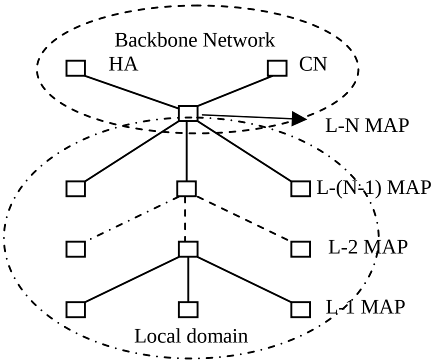

Figure 1. Proposed Network Architecture

Entire network is divided into two parts: backbone network and local domain. The backbone network is formed by the interconnection of top-level gateways of Internet. A local domain is the region covering all the routers under a single top-level gateway. The top layer (layer-N) consists of a single MAP (Global MAP or GMAP) and is located in the border of the local domain. Each L1-MAP covers one or more Access Routers (ARs) that serves one or group of mobile nodes (MN). The region covered by an AR is called a cell. Every MN receives incoming packets via AR. The coverage of the top-level gateway within which an MN registers permanently is called MN's home domain. When an MN visits a network other than its home domain the visited domain is called foreign domain or foreign network. During its visit to a foreign network the visitor MN has to resister with an AR near to it, which provides a Link Care of Address (LCoA) to the visitor MN and also supplies a group of Care of Addresses (CoA) depending upon the level of hierarchies in the architecture. Every time it changes its AR it has to acquire a new LCoA and needs to perform binding update by exchanging BU/BACK between MN and L1-MAP. If the new AR of the visitor MN is not under the same L1-MAP then BU/BACK exchange takes place with higher-level MAPs. At the moment the visitor MN crosses the L-N MAP (or GMAP), the HA of the visitor MN and all the CNs that the visitor MN communicates with during its stay in the foreign domain, need to be updated.

5. Mathematical Modeling of Performance Parameters

For simplicity of computation we have used hop counts as basic unit of measurement. Cost of transmission is computed as a product of number of bytes transmitted with hop count. Figure 2 shows the packet transmission cost from CN to MN visiting a foreign network [4]. When a datagram is received by a HA for the MN currently visiting a foreign network, it sends the data packet to the concerned GMAP and also inform the CN about the MN's new location. After that the new datagram for MN is sent directly to GMAP from the CN. Every packet received by the GMAP is tunneled and sent to next lower level MAP, up to L1-MAP. Finally, L1-MAP tunnels it to AR and AR delivers it to MN. Any message to CN is sent independently via AR and needs no tunneling.

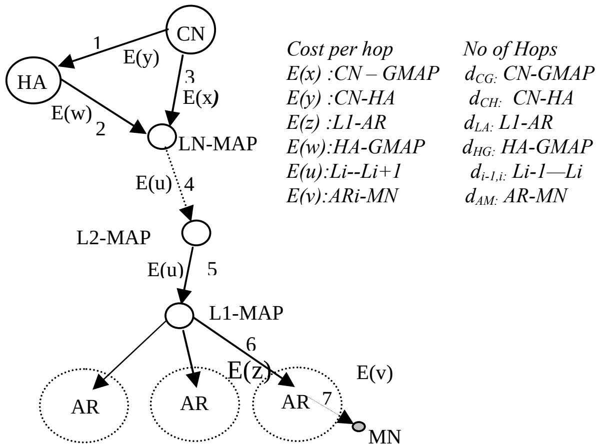

Figure 2. Data Transmission from CN to MN with unit cost

5.1. Handoff Latency Analysis

In this section handoff latency is mathematically computed for the network architecture given in Fig. 1 and taking into consideration the transmission cost depicted in Fig 2. The Handoff latency is defined as the time taken to complete the location update process, starting from the initiation of update process in the old AR to the reception of the first packet in the new AR. The BU/BACK messages to complete the binding update process traverses through various anchor agents. As mentioned in section 1, a queue of type M/M/1/K is maintained at each of the anchor agent in the architecture and the packet arrival rate λ obeys Poisson's distribution. With these assumptions, the handoff latency can be characterized by three different time instances. First, the Router Advertisement (RA) processing time t_{p_ra} requires to construct the LCoA and other CoAs by the visitor MN; second, $t_{p,}$ the time taken to transmit BU/BACK packets between MN and the respective anchor agent; third, t_q, the queuing time of packets at anchor agent. The visitor MN uses stateless auto configuration [9] to construct LCoA from the RA messages. The t_p is influenced only by the distance between the MN and the respective anchor agent, which is required to be updated. The third quantity, t_q depends upon the length of the queue at the anchor agent. First let us calculate the queuing delay [4]. Let ρ is the density of the queue, i.e. number of already accepted packets; K is the maximum (and finite) number of packets that could reside in the queue and t_s is the packet service time, then

$$\rho = \frac{\lambda}{t_s} \qquad (1)$$

The probability that the queue can have j number of packets at any instant of time, denoted by p_j, is computed as,

$$p_j = \frac{(1-\rho)\rho^j}{1-\rho^{K+1}} = \frac{1}{\sum_{i=0}^{K} \rho^{i-j}} \ldots .j = 0,1,\ldots .K$$

Based on this probability, the length of the queue L at any moment could be calculated as

$$L = \sum_{j=0}^{K} jp_j \qquad (2)$$

If L equals to the capacity of the queue then the packet will be dropped, otherwise it will be accepted. The probability of a packet being accepted by the queue η is given by,

$$\eta = 1 - p_K \qquad (3)$$

The queuing time t_q, may be now defined according to Little's formula as,

$$t_q = L/\eta \qquad (4)$$

We use the term t_{qi}, which is basically computed by equation (4) to denote the queuing time at *i-th* layer anchor agent in the rest of the paper. The queuing time of a packet is mainly dependent on the length of the queue at the moment the packet arrived at the anchor agent and the rate of processing of packets at the anchor agent. Irrespective of the type of the packet, whether it is a BU/BACK or a data packet, an anchor agent takes equal amount of time to process a single byte of data.

The second component, t_p, the cost of propagation of the *BU/BACK* messages from MN to *i-th* layer anchor agent is dependent on hop counts between them and neither traffic pattern nor the processing capability of anchor agent can influence this parameter. It is calculated as

$$t_p = 2.s.t_u.d^i_{MN} \qquad (5)$$

where, s is the size of *BU/BACK* packets, t_u is the transmission cost per byte per unit distance, d^i_{MN} is the distance between MN and *i-th* layer anchor agent (figure 2). Hence, the total handoff latency is calculated as,

$$T_l = \sum_{i=1}^{N} 2.s.t_u\{d^{GMAP}_{MN} + \left\lfloor \frac{i}{N} \right\rfloor .d^{HA-CN}_{MN}\} + t_{qi} + t_{p\_ra} \qquad (6)$$

where,

$$d^{GMAP}_{MN} = E(v).d^{AR}_{MN} + E(z).d^{L1}_{AR} + E(u).d^{Li+1}_{Li}$$

and

$$d^{HA-CN}_{MN} = d^{GMAP}_{MN} + E(w).d^{GMAP}_{HA} + E(x).d^{GMAP}_{CN}$$

When $i=N$, the *BU/BACK* messages are communicated between MN and the HA, otherwise they are not. So, the term $\left\lfloor \frac{i}{N} \right\rfloor$ contributes to the total handoff only in that condition.

5.2. Packet Dropping Probability at Anchor agent

Processing capability, maximum allowed queue length, and available outgoing lines (called channels), restrict anchor agent to allow all the packets to pass through. So, few of the incoming packets destined to various MNs are blocked or dropped at each of the anchor agents. We assume that the average packet arrival rate at an anchor agent per MN is λ and T unit time is required to transmit the complete packet. If there are m number of MNs under the coverage of L1-MAP, then the offered load at L1-MAP is given by,

$$a = m.\lambda.T \qquad (7)$$

A packet is queued when all the outgoing routes (channels) are busy and dropped if queue is full. The steady state probability *P(i)* at the M/M/1/K queue of the anchor agent of all the channels are same [10,11] for all i=0, 1, ⋯, S, which is given as,

$$P(i) = \frac{a^i}{i!}P(0) \qquad (8)$$

where, a is the offered load and

$$P(0) = \left[\sum_{i=0}^{s} \frac{a^i}{i!}\right]^{-1} \qquad (9)$$

Packet dropping probability is calculated as

$$P(S) = \frac{a^S/S!}{\sum_{i=0}^{S} a^i/i!} \qquad (10)$$

The packet dropping probability is entirely dependent on the offered load and the queuing capacity at the anchor agent. Also, at each of the anchor agents the offered load is determined by the amount of mobile nodes under its coverage. Alternately, the offered load and hence the packet dropping probability at each of the anchor agents is determined by the number of MNs under it. Equation (10) is the packet dropping probability at L1-MAP. For *n-th* layer anchor agent, value of offered load will be calculated in terms of MNs under L1-MAP and the value of *n*. That is, offered load at *n-th* layer anchor agent is

$$a_n = m.2^{n-1}.\lambda.T \qquad (11)$$

5.3. Efficiency of Anchor agent

In a layered architecture, anchor agent plays a vital role for the success of the model. Resources in the anchor agents are very precious and need to be utilized efficiently. In this section, we analytically compute the efficiency of the anchor agents at different levels of hierarchy. This analysis is primarily dependent on the parameters computed in the previous section by equation (10) and (11) [10, 11]. The efficiency is measured as a ratio of the fraction of traffic allowed to pass to the ratio of total traffic in the anchor agent. Equation (10) gives the fraction of traffic which is blocked at the *n-th* anchor agent. From this equation we can compute the fraction of traffic which is allowed to pass through the *n-th* layer (A_s) as

$$A_s = 1 - P(s) \qquad (12)$$

Equation (11) is the amount of traffic injected to the *n-th* layer agent. Hence from equation (11) and (12) total traffic allowed to pass through the *n-th* layer agent denoted by T_{pass}, may be calculated as

$$T_{pass} = a * A_s \qquad (13)$$

Using equation (13) and (14) the efficiency of the *n-th* layer anchor agent A_{effi}, is computed as:

$$A_{eff} = \frac{T_{pass}}{a} \qquad (14)$$

Equation (14) is another form of equation (12). It implies that, the efficiency of the anchor agent is measured by the amount of traffic forwarded by the anchor agent. So, the efficiency is dependent on both number of outgoing channels and processing capability of the anchor agent, as well as the offered traffic in that anchor agent. In the analytical results section, we will see that the number of layers in the hierarchy has significant contribution to the efficiency of the *n-th* layer anchor agent.

6. Discussion of Analytical Results

Based on the mathematical formulation of section 5, we have computed the results by replacing different parameters of various equations in the section with some real life values. The values for these parameters assumed here is collected from literatures like [3,4,5,7,10] etc. To obtain these numerical results, programs are written in 'C' programming language and results are obtained by executing them. This section shows a graphical representation of these results for all the three performance parameters, handoff latency experienced by MNs for increasing layers of hierarchy, packet dropping probability at *n-th* layer anchor agent, and efficiency of *n-th* layer anchor agent for varying number of layers. For all the graphs presented in this section, an appropriate explanation is provided to understand the pattern followed by them. From these results, we wanted to establish the optimal levels of hierarchy, which can give seamless mobility to mobile end users with optimal values for observed parameters.

6.1. Handoff Latency

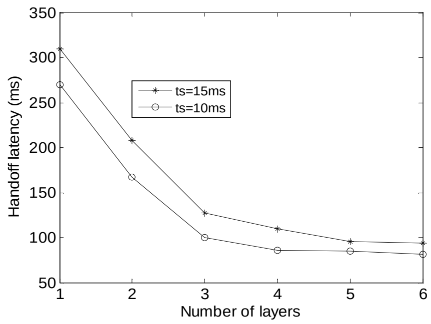

Figure 3. Handoff latency Vs Layers

To see the change in handoff latency experienced by MNs, observation is started with a single layer placing the anchor agent at the border of the local domain. Then we increase the number of layers with almost same distance (in terms of hop count) between two successive anchor agents. Observation reveals that with a single anchor agent at the border of the local domain the handoff latency is around *300ms* (figure 3). As number of layers increases, the handoff latency decreases. Latency sharply falls up to layer four with average reduction of around *80-100ms* and after that it decreases very slowly. Only *10-20ms* reduction in latency is found for layer five and six. The data plotted in the graph is for t_s*=10* and *15 ms* and speed of MN is *10 m/s*.

The handoff latency depends upon the number of layers in the MAP hierarchy as well as the processing time at the queue maintained in these MAPs. Queuing delay or the processing time at the queue is also influenced by the number of lower level anchor agents and hence the number of MNs under L1-MAP. In a queue, the probability of a packet being accepted by a queue is dependent on maximum allowed packets in the queue K and the density of packets (i.e. number of already accepted packets). To reduce the packet loss, density ρ must be kept at minimum and the queue capacity K at large value [4]. If we consider K as constant, increasing the processing ability of the MAP could minimize ρ. The value $t_s=10ms$ and *15ms* are assumed as processing time of a packet [12, 13] in the observation.

6.2. Packet Dropping Probability

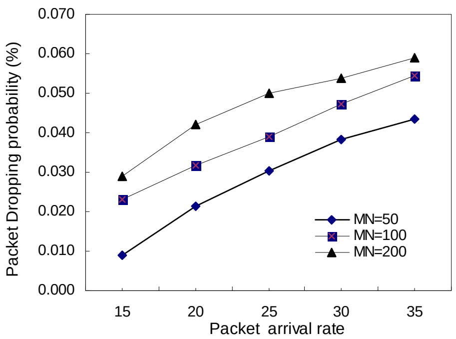

Figure 4. Packet dropping probability Vs packet arrival rate

A measure of packet dropping probability at *n-th* level anchor agent with respect to packet arrival rate is shown in Fig. 4. Three graphs in the figure represent the characteristic of packet dropping probability at *n-th* layer anchor agent with similar packet arrival rate but considering number of MNs as *50, 100* and *200* under L1-MAP. Figure 4 shows that for *50* MNs under L1-MAP packet dropping probability at the *n-th* layer anchor agent with a packet arrival rate of *15* is the lowest and it remains below 5% for other rates. When number of MNs under L1-MAP *is 100* and *200*, packet dropping probability goes above *5%* for higher arrival rate (*30* and *35*). So, to see the packet dropping probability at each of the layer values for *50* MN per L1-MAP, packet arrival rate *15, 25* and *35* are considered in Fig. 5.

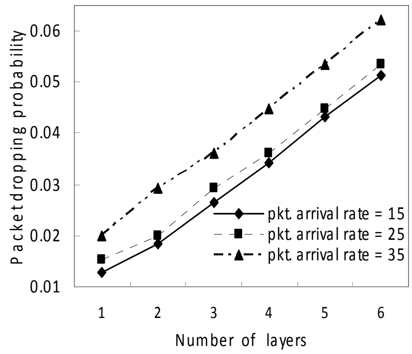

Figure 5. Packet dropping probability Vs layers

Fig. 5 shows the packet dropping probability for average packet arrival rate *15, 25* and *35* per *MN.* The number of MNs under L1-MAP is considered as *50 (i.e. m=50)*. Since anchor agents are organized as a tree, there are $2^{n-1}.m$ number of mobile nodes under the coverage of *n-th* layer anchor agent. The graph shows that packet dropping probability remains within *2%* up to layer two, *2-3%* up to layer four and more than *5%* beyond layer four when packet arrival rate is *15*. For average packet arrival rate *25*, packet dropping probability exceeds 5% at layer four and above. For packet arrival rate *35*, 5% of packet dropping probability exceeds at layer three and above. So, from packet dropping probability point of view, three to four levels of hierarchy may be considered suitable when packet arrival rate per MN is less than *35* and MNs per L1-MAP is around *50*. But considering both handoff latency and dropping probability, three levels of hierarchy in the architecture may be considered optimal.

6.3. Efficiency of Anchor Agent

To measure the efficiency of anchor agent in different layers, four sets of data with different values of average packet arrival rate and number of MNs per L-1 MAP is considered. When packet arrival rate and number of MN per L1-MAP is the least (*packet arrival rate=5 and MN per L1-MAP=50),* the efficiency of the anchor agent is around *99.8-99.9%* up to six layers. In this low arrival rate an anchor agent can successfully forward all packets arrived at it. As soon as the packet arrival rate and MN per L1-MAP increase, efficiency decreases with increasing number of layers. For *packet arrival rate=15* and *MN per L1-MAP=100*, efficiency comes down to around 97% at layer 5 and for *packet arrival rate=25* and *MN per L1-MAP=200* efficiency goes around *95%* at layer 5 and around 90% at layer 6. For final set of (*packet arrival rate=40 and MN per L1-MAP=250)* efficiency is around

95% at layer three and it sharply decreases to around *80%* beyond layer three.

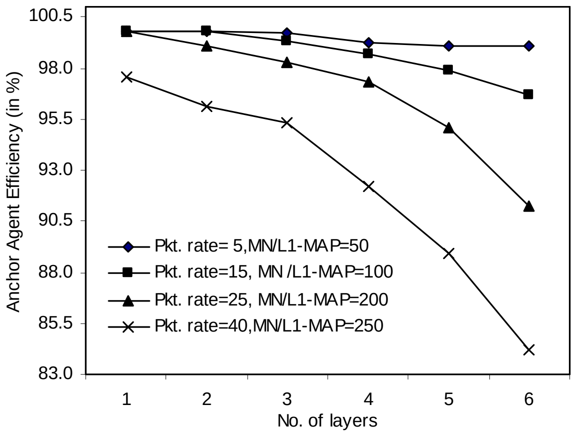

Figure 6. Anchor Agent efficiency Vs layers

From the discussion above it may be assumed that as soon as the numbers of layers increase the efficiency of the anchor agents decreases. But in most of the cases efficiency of the anchor agent is around *97-98%* for three layers. Hence, we may consider three layer architecture may be suitable as far as anchor agents' efficiency is concerned. In Table -1 some of the parameters used in the analysis are given.

Table 1: Parameter used for numerical analysis

E(z)	E(u)	E(v)	E(w)	E(x)	E(y)	K	T
1	1	1	1	1	1	20	10
d_{HA}^{GMAP}		d_{CN}^{GMAP}		d_{Li}^{Li+1}		d_{AR}^{L1}	
6		4		3		2	

7. Conclusion

In this paper, handoff latency and packet dropping probability at different anchor agents for *n*-layered MIPv6 based architecture is being analyzed mathematically. We test the model under different traffic arrival patterns and MN density. Analysis shows that handoff latency decreases by a ratio of *25-35%* in addition of a new layer up to three layers, around *15%* decrease on adding fourth layer and a negligible decrease of *2-3%* beyond layer four. A three-layered architecture provides optimal handoff delay. Again, level of three to four in the hierarchy is good in terms of packet dropping probability considering above *5%* packet drop is unacceptable [8]. The efficiency of anchor agent remains above *96-97%* up to three layers, after layer three and beyond, efficiency of anchor agent degrades. So a three-layered architecture may be adopted for next generation IPv6 based distributed network. Low handoff latency implies a better QoS to the end users. Also, in a situation where users are more sensitive to the disruption in the ongoing communication, this model provides better quality of service as only *2-5%* packets are dropped.

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