DOUBLE BUFFER MODEL FOR WIRELESS IP NETWORKS

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Abstract

The growth of cellular radio communications in the past decade has been remarkable. Demand for cellular communications has placed heavy demand on the capacity of wireless interfaces and the network resources available. As a result, the demand for higher transmission speed and mobility is even greater. In this paper, we investigated the performance of Double Buffer Technique (DBT) model for mobility support in wireless IP networks. The DBT model uses the END message and Time Quantum for Real-time Services (TQRS) timer to maintain the packet sequence and decrease the load on the new foreign agent when the timer expires, respectively. Also, the protocol showed improved performance degradation caused by the handover of the mobile terminal. In order to demonstrate the superiority of our scheme over the existing ones, we used the following performance metrics: packet out-of-sequence, cell loss ratio, bandwidth overhead, and suitability for real-time services. The numerical results obtained revealed that the buffer size, the waiting time, and the packet loss probabilities in the model were suitable to the wireless IP environment.

Keywords: cellular, mobility, wireless, handover, Double Buffer Technique, seamless, QoS

1.0 INTRODUCTION

Internet work of the future includes networks of small wireless cells populated by large numbers of portable devices. Laptop and cellular telephones have proven their utility, while advances in miniaturization promise functional portable devices. Networks of small wireless cells offer high aggregate bandwidth, support low-powered mobile transceivers, and provide accurate location information [1]. The changing needs of the business world and the availability of new technologies have led to the emergence of mobile Internet Protocol (IP) for mobility support in wireless IP networks. Mobile communications and the Internet are expected to be the main drivers for today’s and tomorrow’s business. This is more so as new and novel kinds of value-added services over wireless broadband connections are emerging. According to [2] [3], today’s Internet does not fully support mobility. In fact, the Internet’s routing and addressing structure prohibits packets addressed to a roaming mobile node from reaching it without specific support for mobility.

The importance of portable computing and telecommunication applications motivate the fast development of high speed wireless networking technologies. Especially with the increasingly mainstream role of multimedia laptops, PCs, Personal Digital Assistants (PDAs) and Personal Information Assistants (PIAs) require communication techniques with higher and more flexible bandwidth [4]. The growth of cellular radio communications in the past decade has been remarkable. Demand for cellular communications has placed heavy demand on the capacity of wireless interfaces and the network resources available. As a result, the demand for higher transmission speed and mobility is even greater. These have led to an increasing need for supporting users` mobility in today's computing environment through the Internet. One of the most important things to support terminal's mobility is the location management in the Internet. The Internet Engineering Task Force (IETF) defines Mobile Internet Protocols (IP) based on forwarding pointer concepts, which has as an extension the Route Optimization Protocol (ROP). There are some problems associated with the mobile terminal's entry as it crosses cell boundaries especially in the midst of data transfer. One of them is the packet out-of-sequences caused by the frequent handovers of the mobile terminal. In this paper, the authors examine the mobility issues in wireless IP networks and proposed a Double Buffer Technique (DBT) model for guaranteeing the packet sequence.

2.0 CELLULAR COMMUNICATION AND MOBILE IP

Cellular technology is based on geographical areas called cells. Each cell includes a base station that subscribers within the cell communicate with using two Radio Frequency (RF) links. All transmissions are full duplex, and one RF link is used for transmitting information, while the other is used for receiving [5, 6]. According to [7], mobility can be described as the ability to use a single logical label by any user to access an entity wherever the latter is within the network. With mobility, the caller does not need to determine where the entity is and the corresponding network address.

In [7], MIP is an Internet Protocol designed to support terminal mobility. Its goal is to provide the ability for a terminal to communicate with corresponding node connected to Internet regardless of their location. Mobile IP is able to track a Mobile Terminal (MT) without needing to change its long-term IP address. It has two servers i.e. the home agent and foreign agent. They are typically routers in the MT`s home network, and it contains a Mobility Binding Table mapping the MT`s permanent IP address to its temporary IP address called the Care-of-Address (CoA), which stands for the current location of the MT. Other important features of the MIP are the Agent Discovery and Registration functions.

In cellular networks, it is not efficient that all packets destined to a MT must be routed through the MT`s home agent. This can be achieved using the triangle routing scheme. To solve this triangle problem, ROP extends the concept of the basic MIP in order to achieve optimization of routing from a corresponding node to an MT through eliminating the home agent (HA). All packets destined to the MT are routed directly to the current foreign agent of the MT. Figure 1 describe the ROP scheme, in which the sender can make a "tunnel" to the foreign agent directly. The Update Process in Figure 1 represents that the home agent transfers the Registration message to the sender i.e. the corresponding node, and the foreign agent updates the Binding Cache according to the received Registration message. According to [8], there are several reasons for using the mobile agent concept. Some of the reasons are suitable to the implementation of mobile IP architecture, and these are: Network load reduction; Overcoming network latency; Asynchronous and autonomous execution and Dynamic adaptation.

3.0 MOBILITY IN WIRELESS IP NETWORKS

In a cellular network, it is not unusual for a mobile device to cross cell boundaries during a data transfer using the MIP. In this case, it is possible for some packets to be delivered to the previous foreign agent rather than the current foreign agent due to the MT's handover procedure such as leaving a cell, joining a new cell, and processing registration. The packets that are transferred to the old foreign agent lose their path going to the MT. These packets which lose their route are called orphan packets and cause a packet loss, packet out-of-sequence, retransmissions, and duplicated acknowledgements. Figure 2 represents the time diagram of packet transmission and acknowledgement just after terminal's handover. Since packets 8 and 9 arrive earlier than packet 3, three acknowledgements are transmitted to the sender resulting in the retransmission of packet 3. A number of proposals have been made for the purpose of correcting the inherent errors. Some of these research efforts, according to [7], are: ignoring the orphan packets, waiting for the orphan packets during a fixed time and using a "Refuge Proxy"..

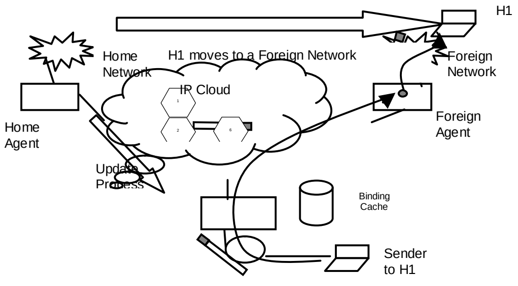


Fig. 1: Route Optimization Scheme in Mobile IP

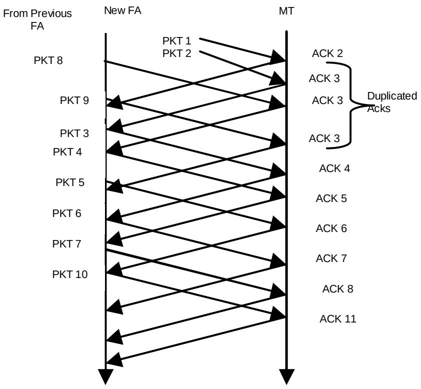


Fig. 2: Time Diagram of Packet Transmission and Acknowledgement

4.0 SYSTEM MODEL

According to [8], the DBT model uses two messages i.e. the END message and the Time Quantum for Real-time Services (TQRS). Figure 3 shows the DBT protocol. When the MT moves to the new foreign agent's network, it sends a registration message with a TQRS value to the new foreign agent. Then the new foreign agent sends the registration message to the home agent and binding update message with TQRS to the previous foreign agent. After registration in the new foreign agent's network and on the receipt of the END message, it starts transferring the stored message (i.e. packets) to the MT [9]. Each agent has a Mobility Binding Table where it keeps the addresses of all the MTs in its network. This table resides in the Address Resolution Protocol (ARP) cache. Figure 4 shows the structure of the table.

4.1 Model analysis

Let the packet arrival has a mean (i.e. average rate of packet arrival):

Mean Packet Arrival = λ_p packets/second (1)

Therefore, the mean packet service rate can be represented as:, P = C/• p, Where C = Capacity of the wireless line and • p = Number of served packet. The inter-arrival time of activation of mobile terminals for transferring the data and the one of handover terminal has an exponential distribution with parameters l_{M}^{-1} and l_{H}^{-1} respectively. The holding times of those two kinds of cells have the exponential distribution with the mean of m_{M}^{-1}.

Let K(t) be the number of packets in the buffer and A (t) be the arrival rate of the packets. Since the packet arrival rate depends on the number of calls, the packet arrival rate A(t) at the new foreign agent can be calculated by:

$$A(t) = n(t) * l p \quad (2)$$

where n(t) = number of calls at a given time.

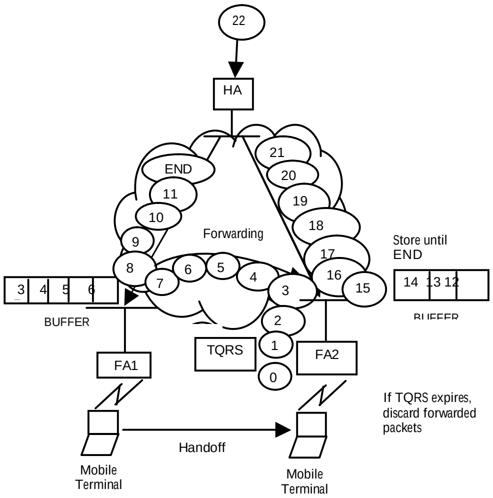


Fig. 3: The Proposed DBT Protocol / Model

BINDING TABLE	
Permanent IP address	Temporary IP address
MT = A	CoA = B

Fig. 4: Structure of the Mobility Binding Table

It is clear that the number of call increases when the mobile terminal is active in the region controlled by the new foreign agent or when the handover mobile terminal arrives. It is to be noted that n(t) has a Poison Process with parameter $•_H + •_M$. Then, the system can be modeled as a two-dimensional process, characterized by (n(t), K(t), where n(t) and K(t) is the number of call and the number of packets in the system, respectively. The state space is represented by the set: $[S(n,K) \mid 0 \le n \le n_{max}, 0 \le K \le K_{max}]$; where n_{max} is the maximum call number and K_{max} is the maximum buffer size. To analyze the state of the buffer, we consider the time interval starting at t and ending at t + •t., where •t is an infinitesimal time increment as (•t → 0). The following possible transmissions could occur during the time interval (t, t + •t) a packet enters state n from state n-1 with flow rate $•P_{n-1}$; a packet enter state n and from state n+1 with flow rate $•P_{n+1}$; a packet leaves state n and enters state n-1 with flow rate $•P_n$; a packet leaves state n and enters state n+1 with a flow rate $•P_n$.

Flow into state n = $•P_{n-1} + •P_{n+1}$

Flow out of state n = $•P_n + •P_n$

Hence:

$$l P_{n-1} + m P_{n+1} = (l + m) P_n \tag{3}$$

But the number of

$$S_i \rightarrow S_{i+1} = S_{i+1} \rightarrow S_i$$

Then: $l\, P_o = m\, P_1 ;\; P_1 = \frac{l}{m} P_o$ (4)

Where $\frac{l}{m}$ = *traffic intensity* ; Assuming the buffer size is N, and the sum of state probability is 1:

$\sum_{n=0}^{N} P_n = 1$ *implies* $P_o \sum_{n=0}^{N} r_n ;\; = P_o \left(\frac{1 - r^{N+1}}{1 - r} \right)$; and using sum of geometric progression, therefore:

$$P_o = \frac{1 - r}{1 - r^{n+1}} ; \qquad P_n = p^n \left(\frac{1 - r}{1 - r^{n+1}} \right) \text{for } 0 \le K \quad = 0 \text{ otherwise.}$$

The probability that there are N messages is the same as when the buffer is in state P_N. Therefore:

$$P_N = P_o r^N = \left(\frac{1 - r}{1 - r^{N+1}} \right) r^N \qquad (5)$$

= Probability of overflow.

Note that the packet will be lost if the packet arrives to the system whose system state is in S(n,K) for 0 ≤ n ≤ N. Thus, the loss probability for the packet can be written by:

$$P_B = \left[\frac{\sum_{n=0}^{N_{\max}} n\, l_p p\, (n, K_{\text{Max}})}{\sum_{n=0}^{N_{\max}} \sum_{k=0}^{K_{\max}} n\, l_p p\, (n, K)} \right] \qquad (6)$$

In the DBT scheme, we will assume that T_{END} is the END message trip time and $T_{NEW\ FA}$ be the transmission time for one packet between the home agent and the new foreign agent after handover. Each connection generates the packets with arrival rate $\bullet_P$. The superposition arrival rate of the packet depends upon the number of connection N(t). Figure 5 shows the system model for the mobile agent supporting the DBT protocol. The number of temporary buffer size is denoted as i. It is clear that the number of queued packet I is the same as the number of packets arriving during the time:[10]

$$T_{Buf} = T_{END} - T_{NEW\ FA} \qquad (7)$$

Then, the average number of packets to be queued (P_Q) can be written by:

$$P_Q = T_{Buf} * \lambda_p \qquad (8)$$

5.0 SYSTEM SIMULATION AND RESULTS ANALYSIS

The simulation environment was abstracted as a two-dimensional space divided into regions managed by different agents. The mobile terminal normally starts off from mobile agent 0, which it registers with as its home agent. The position of the mobile terminal is given by the vector, P, such that:

$$P = x_{\underline{i}} + y_{\underline{j}} \tag{9}$$

Where (x, y) represents the x and y coordinates of the mobile terminal at any instance of time. The motion of the mobile terminal is simulated by giving it a velocity given by:

$$\vec{V} = V_{xi} + V_{yj} \tag{10}$$

and the initial location of the mobile terminal is given by:

$$P_o = x_{o\underline{i}} + y_{oj} \tag{11}$$

where (x_o, y_o) are the initial starting location coordinates x and y of the mobile terminal. Generally, the default starting point of the mobile terminal is such that:

$$x_o = y_o = 0 \tag{12}$$

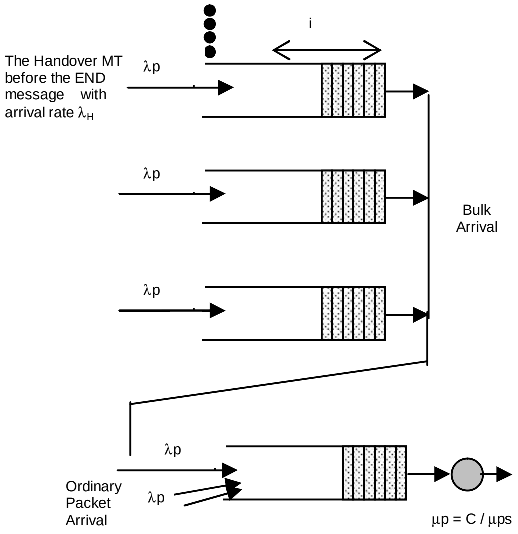
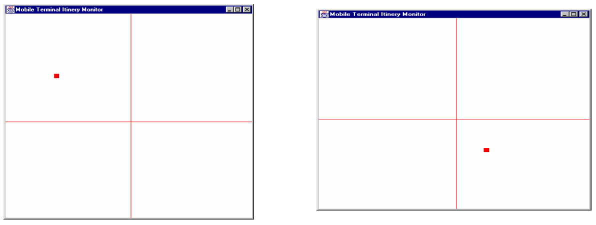
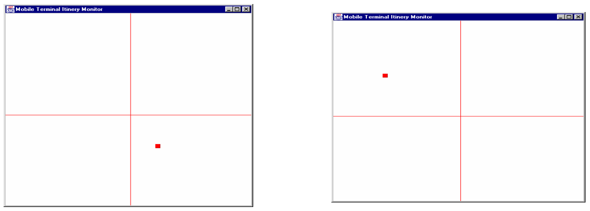


Fig. 5: System Model for Mobile Agent Supporting DBT Protocol



(a) MT in Home Network © MT in Foreign Network Four



(b) MT in Foreign Network (d) MT in Foreign Network Two

Fig. 6: Different Positions of the Mobile Terminal

Figure 6 shows the possible four different positions of the mobile terminal. In real life situation, the owner of a mobile terminal can lose contact with the cellular network if he is outside the boundaries of the cells. To prevent this in the simulation, the mobile terminal bounces off the boundaries of the simulation environment. The velocities of the mobile terminal are assigned randomly using the multiplicative congruential pseudorandom number generator.

5.1 Numerical results and discussion

The various performance metrics used for the comparison are discussed in the following sub-sections.

5.1.1 Packet Out-of-Sequence

The cells reaching a mobile terminal are numbered and should be in the same order as they were generated from the cells' source. Hence, the cells generated from the cells' source can be represented by a set X given by:

$$X = \{x : x_i^{\prime} \ \mathrm{p} \ x_{i+1}^{\prime}\} \qquad (13)$$

Where: x is the set of cells generated from the source; x_i is the i^{th} cell reaching the mobile terminal. and x'_i is the sequence number of the i^{th} cell. i is an integer value given by the set {0, 1, 2, ..., n-1}

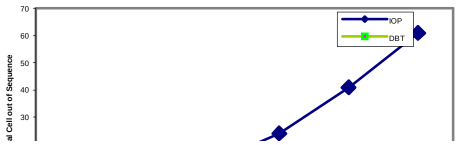
Where: n is the total number of cells sent from the source.

We say that we have a cell out-of-sequence condition when the set of cells reaching the mobile terminal is given by:

$$x_{out} = \{x : x_i^{\prime} \ \mathrm{f} \ x_{i+1}^{\prime}\} \qquad (14)$$

$$\textit{for any } i; 0 < i < n$$

During the simulation, while varying the total number of cells used in a session, the amount of cell out-of-sequence encountered in both the DBT and the IOP schemes were measured. Figure 7 shows the amount of cell out-of-sequence for these two techniques. As could be seen, the DBT scheme never had an out-of-sequence cell condition as opposed to the IOP scheme whose cell out-of-sequence value increases as the total number of cells in a session increases. In the DBT scheme, the buffers are dynamic and could handle bursty traffic dynamically due to its scalability.



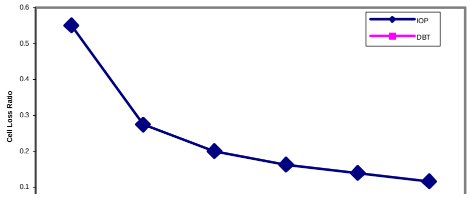


Fig. 7: Degree of Packet Out-of-Sequence in IOP and DBT

Fig. 8: Cell Loss Ratio in IOP and DBT Schemes

5.1.2 The Cell Loss Ratio (CLR)

The Cell Loss Ratio (CLR) is another important measure of performance for the different cell management techniques in the wireless architecture. It is a negotiated QoS value for the various applications supported by the network protocol. The Cell Loss Ratio is given by:

$$CLR = \frac{C_L}{C_T} \tag{15}$$

Where: C_L = Total number of cells lost during a transmission session; C_T = Total number of cells transmitted in a session.

The CLR is a negotiated performance parameter depending on the quality of service of the application. As can be seen in Figure 8, the dynamic and scalable buffer size in the DBT scheme does not allow cell loss during the transmission session hence; the perpetually void cell loss ratio. This is unlike the IOP scheme.

5.1.3 Bandwidth Overhead

In the Ignore Orphan Packet (IOP) scheme, lost packets are attempted to be retransmitted on the reception of duplicated acknowledgments, this retransmission of lost cells coupled with the duplicated ACKs constitutes bandwidth overhead hence the bandwidth overhead incurred by the IOP scheme is a direct function of the total number of repeated acknowledgements and retransmitted packets encountered in a session.

The DBT scheme uses an END message to signal the end of a segment of transmission to an agent; this protocol in the algorithm is an overhead in terms of bandwidth usage, hence it represents bandwidth overhead in the DBT scheme. The network bandwidth overhead incurred by the cells carrying the END message is lower than the overhead caused by the packet retransmissions and duplicated acknowledgements in IOP scheme. Figure 9 shows the comparison of the bandwidth overhead incurred by the DBT and IOP schemes.

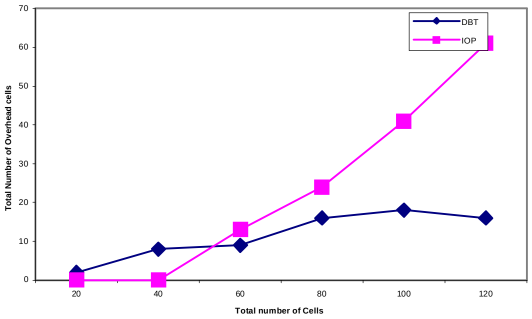


Fig. 9: Degree of Packet Out-of-Sequence in IOP and DBT Schemes

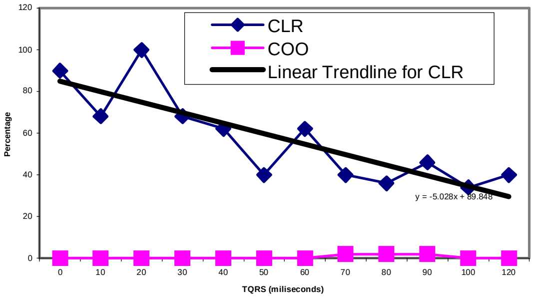


Fig. 10: Suitability of DBT Scheme for Real-time Services

5.1.4 Time Quantum for Real-time Services (TQRS)

The TQRS was used to determine the way the orphan packets were managed. The inequalities below shows the values assigned to TQRS under various conditions.

$0 < TQRS < MAX\_TIMER$ waiting a given time

$TQRS < 0$ no saving of out-of-order packets (16)

$TQRS = 0$ discarding the orphan packets

From (16), it can be observed that TQRS is inversely proportional to QoS i. e. A constant value of unity was assumed for the purpose of the simulation. Hence;

$$TQRS = \frac{1}{QoS} \qquad (17)$$

Also, TQRS is inversely proportional to CLR i. e. assuming a constant of unity also, we will have:

$$TQRS = \frac{1}{CLR} \qquad (18)$$

This is because the higher the QoS, the higher the CLR due to the fact that the application will not wait for lost or orphan packets, hence; CLR is directly proportional to QoS, i. e. $CLR \propto QoS$ (From equations 17 and 18) The suitability of the DBT protocol for real-time applications was tested with various values of the TQRS. Figure 10 shows the suitability of the DBT technique for real-time services. The more real-time an application is, the lower its TQRS meaning that at the limit, an application that is a perfect real-time which cannot tolerate any delay will have a TQRS of zero. This is not possible in practice because that will give an infinite value to the CLR (from equation 18). From Figure 11, the DBT scheme has an increasing cell loss ratio with decreasing TQRS as represented by the linear trend line for the cell loss ratio curve that has the equation:

$$y = - 5.028x + 89.848 \tag{19}$$

From the curve, it can be observed that it has a negative slope of -5.028. This shows that the CLR increases with decreasing TQRS (from Figure 18) making the DBT scheme less efficient for real-time services with high QoS values. Also due to the buffering, it is unsuitable for applications with low TQRS that demands less cell losses. Incidentally, the cell out-of-sequence is still managed very well even with varying TQRS. However, this is expected to work for mobile IP networks as it is not a perfect real-time technology.

6.0 CONCLUSION AND FUTURE RESEARCH DIRECTIONS

In this paper, we have investigated the performance analysis of DBT model for mobility support in wireless IP networks. Mobile services offer advantages that can help cellular networks. The proposed DBT protocol in this research effort maintained the packet sequence using the END message and buffering in the new and old foreign networks, and it also has the TQRS timer so that we can decrease the load on the new foreign agent by discarding the packets when the value of the TQRS timer expires. From the numerical results obtained from the simulation, we can also deduce that the proposed DBT protocol is suitable in the practical environment. Since mobile communications are harder to secure than traditional wire-line communications; we will, in future, investigate the automated verification of itinerant codes through program analysis to detect potential security threats.

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