



Mitigating the Effect of Ping Pong in LTE Advanced Networks Based on a Modified Adaptive Based Handover Decision Technique

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ABSTRACT

With the continuous expansion in telecommunication networks, the need for high data rates, and low latency for user equipment has become a research challenge in this industry. The Third Generation Partnership Project (3GPP) released Long Term Evolution (LTE) and Long Term Evolution Advanced (LTE-A) in release 8 and 10 respectively which can support different traffic in video, voice and data but create new technical challenges in seamless connectivity for user equipment on the move. Mobility Management is an integral aspect of wireless communication taking into account the handover process as seamless connection between eNodeBs and user terminals on the move. This connection can be made more seamless via adapting handover control parameters such as time to trigger and hysteresis margin. In this paper, an intelligent scheme based on a modified adaptive based handover decision technique is proposed for handover optimization. Adaptive pair values of hysteresis margin and time to trigger parameters were generated and the effect based user equipment velocity and distance away from the eNodeB was analyzed to mitigate the effect of handover ping pong. The simulation results obtained showed decrease in handover ping pong probabilities of 29%, 28% and 13% at 3km/h, 30km/h and 120km/h respectively as compared to the conventional technique. These results obtained can decrease call dropping and subsequently network performance degradation.

Keywords: LTE A, Ping pong, Multi criteria, Adaptive technique, Handover decision, Wireless

1. Introduction

Recently, the continuous need for high data rate and low latency has become a focus of research for the wireless telecommunications networks. A wireless communication network is deployed over a geographical area to provide services such as voice, data and multimedia services to end users (Goyal & Kaushal, 2019).

One of the important challenges in wireless communication is the ability to permit mobility without loss of connectivity or quality of services which is known as mobility management. This plays an important role in system optimization and robustness. It aims to ensure seamless connectivity without degradation in Quality of Service for mobile users. It is one of the most important areas in heterogeneous networks which is still under research to provide seamless communication. Two different mobility management types exist in cellular networks: user equipment (UE) mobility with respect to spectrum and with respect to base station (BS) and also spectrum mobility which is more related to spectrum utilization in cognitive radio technology. (Alhammedi *et al.*, 2018)

Handover is required to provide seamless connectivity. Handover is a process in which a connected user's session is transferred from the current base station to a target base station which is preferred to occur seamlessly. This is practically not possible because handover cannot occur without failure which may be as a result of handover parameters not properly configured or controlled. Handover failures such as too early handover, too late handover, handover not triggered properly and also handover bounces back and forth called



ping pong handover can occur as a result of this (Amer, *et al.*, 2015). The success rate of a handover process is an indicator for user satisfaction therefore the need for the process to be fast and seamless. The conventional handover optimization is time consuming and not as reliable as needed. This led to the development of different self-optimizing handover algorithms which differ by tuning the handover control parameters to enhance the overall system network performance and Quality of Service.

2. Related Works

A survey of recent working, strategy, management, techniques, issues, challenges and finally future works on handoff management in heterogeneous wireless networks was carried out by **Dhand & Dillon (2018)**. Handover phases of initiation, decision and execution were explained in the work and performance metrics for seamless vertical handover such as quality of service, energy efficiency and system performance were analyzed. Emphasis was also made on the need for accurate analysis and measurement of multiple parameters. Analysis on the issues and challenges encountered in next generation wireless networks and also the need for efficient and effective algorithm for handover management were also discussed. The need for cross layer based optimization solution is a major challenge and was recommended that by the incorporation of new mobility management schemes such as adapting parameters to changing environment and real life scenarios. Multi criteria such as velocity, direction, signal to noise ratio (SNR) should also be considered for accurate measurement for mobility optimization. **Zhang *et al.*, (2018)** proposed a self-optimization energy efficiency based handover decision algorithm aimed at improving the energy efficiency of the system and also to minimize handover ping pong rate. The performance metrics hysteresis margin and time to trigger were selected dynamically coupled with signal to interference plus noise ratio were employed based on ping pong handover ratio and current network energy efficiency state based on energy reduction gain. The energy efficiency model established was for checking the energy status of both base station and mobile terminal when changing the handover control parameters. The result obtained showed the superior performance of this algorithm by minimizing the ping pong ratio to 5% and improving the system energy efficiency by 4%. Although parameters employed provided improved self-optimization for a smart phone, a more realistic power consumption with more detailed parameters should be employed for a more robust system.

A dynamic handover control parameter algorithm in heterogeneous networks with dense small cells to minimize the problem of radio link failure, ping pong effect and maximizes the spectral efficiency was proposed by **Alhammadi *et al.*, (2018)**. This handover parameter optimization was deployed between LTE Advanced and millimeter wave networks to mitigate too early, too late, wrong cell and ping pong handovers. Hysteresis Margin and Time to trigger were the two performance metrics used based on 3GPP standard for heterogeneous networks and were optimized dynamically according to mobility scenarios in an inverse relationship to mitigate the problem of too early and too late handover. The results obtained showed an improvement in system performance using this algorithm as compared to static values for most mobile speeds. This dynamic scheme was efficiently implemented taking into account the current state information but considering also the past information can help in predicting better metrics and effectively minimizing the handover problems better. Delay was introduced into the system as a result of inability to adapt the performance metrics into the system and no threshold value was considered to mitigate the ping pong and radio link failure. **Abdullah *et al.*, (2018)** proposed an improved handover decision algorithm based on multi criteria to minimize the probability of number of handover and handover failure. Technique for Order Preference by Similarity to Ideal Solution(TOPSIS) was used which required speed, cost function, radio and network topology to serve as inputs to offer flexibility to determine the weights based on mobile, network and equal weights. The weights are employed were used to calculate the impact of every criterion so as to select the most suitable network for the handover decision process. The performance indicators employed were cost function, mobile speed, RSS and network occupancy using worldwide interoperability for microwave access



(WIMAX), wireless local area network (WLAN) and Long term evolution (LTE) interfaces. The result showed that network weight generated higher output based on number of handover and handover failure probability with 60% and 43% compared to mobile weight with 40.29% and 33.79% and equal weight with 22.9% and 24.62%. This research employed multiple criteria to analyze these interfaces with respect to handover failure but in the process limited the algorithm to small network deployment and inability to process complex systems.

Another interesting work was in adapting hysteresis margin (HM) and time to trigger (TTT) aimed at finding a pair of suitable HM and TTT values based on distance and speed of any user equipment by **Zhang (2018)**. The analysis was based on both macro and a 2 tier heterogeneous network scenario. The objective of the HM was to bind the UE to its original serving cell. The performance indicators employed for the validation were handover too early, handover too late and ping pong ratio. Adaptive technique is one of the most suitable techniques for optimizing handover decision algorithms due to its ability to perform in changing environment and real life scenarios. With this advantage a combined optimization of the parameters involved were not fully considered which eventually increased the delay of the system. The most recent work was proposed by **Goyal & Kaushal (2019)** on handover optimization scheme for LTE Advanced based on AHP/TOPSIS and Q learning to minimize handover ping pong and failure rate. This technique employed the use of multi criteria performance metrics. The metrics used were RSRP, RSRQ, Current load, Uplink SNIR, direction and location of user equipment based on AHP/TOPSIS technique to rank ENodeB and UE while the Q learning technique to choose appropriate HM and TTT for the handover decision process. The result showed how this technique minimized the handover failure rate and Handover ping pong by 28%, 25% and 35% and 33% as compared to conventional technique. The hybridization of the AHP- TOPSIS and Q learning reduced the subjectivity, computational cost and also ease of application but it cannot be analyzed optimally in a large dense network. Q learning which works based on trial and error method increased the computational delay of the system which in turn reduced the overall efficiency of the system.

In Summary, one of the main challenges of vertical handover is mobility management where the need for efficient and effective new handover management scheme is required. The current and future works done to solve this issue involves adapting parameters based on changing environment and ability to input more criteria such as velocity and direction for mobile node accuracy of movement (Dhand & Dillon, 2018). From the literatures reviewed, it showed that handover problem due to ping pong effect is a major problem of handover decision which has not yet been fully exploited. Triggering points of hysteresis margin and time to trigger with respect to different velocities and distances have been adopted in this paper to minimize handover ping pong probability by dynamically adapting them to changing environment which helps reduce the complexity and in turn decrease computational delay of the overall system.

2.1 Theoretical Review

2.1.1 Mobility Management

Mobility Management is an important factor considered in mobile cellular communications systems which aims at the ability to track the location of a mobile terminal on the move while allowing calls, SMS and other network services to have access to it. Some of its functions include handover, rerouting, location updates and paging (Shaukat, 2019). Mobility management is basically characterized into User Equipment mobility with respect to base station (This involves the act of maintaining connection between a user equipment and a base station) and that of spectrum (This involves spectrum utilization most especially in cognitive radio)

(Alhammadi et al., 2018). Mobility management involves mobility and interworking scenarios, handover decision metrics and mobility parameters, handover decision mechanism, handover performance measures and mobility protocols. Therefore, for seamless mobility, a combination of the various categories mentioned above can be used (Zekri, 2012). Mobility management is divided namely into location and handover management as shown in Figure 1. The location management is a process where the network nodes track the mobile nodes through location registration and call paging while handover management involves keeping the connection between a node and a network while on the move (Sen, 2019) The main focus of this paper is on vertical handover decision in terms of triggering conditions estimation.

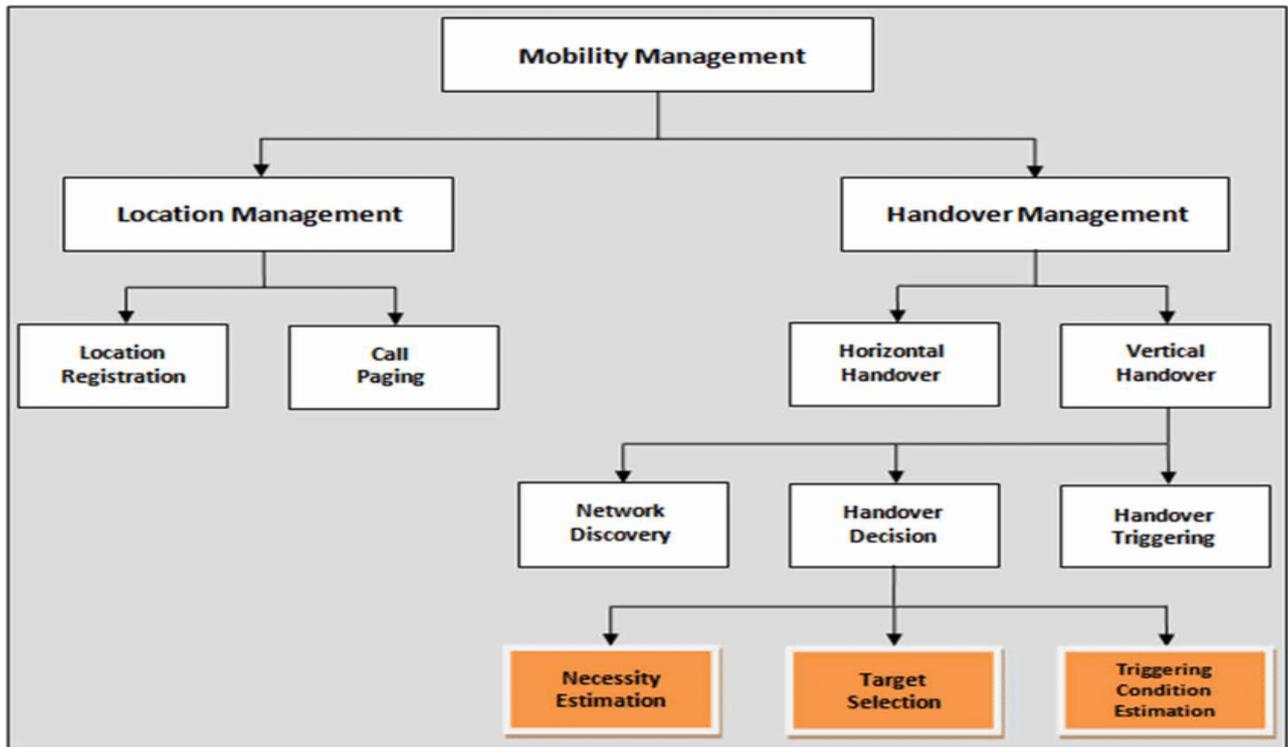


Figure 1. Hierarchy of mobility management in a heterogeneous network environment (Mahmood, *et al.*,2018)

2.1.2. Handover Procedure

Handover is a process involved in the transfer of an ongoing data or voice calls from one location to another while on the move. Figure 2 depicts the handover process and its two broad categories. It is important for this procedure to be fast, seamless and successful for good user satisfaction. Handover can be characterized by the properties of seamless and also lossless. The former deals with the quality of service as user equipment moves from one cell coverage to another while the latter involves the ability of no data to be lost during the procedure (Chavarría, 2014)

Radio network depreciation, decrease in the network parameters of the base station are some of the factors that indicate the need for handover (Orimogunje *et al.*,2018). This handover procedure is clearly depicted in Figure 2

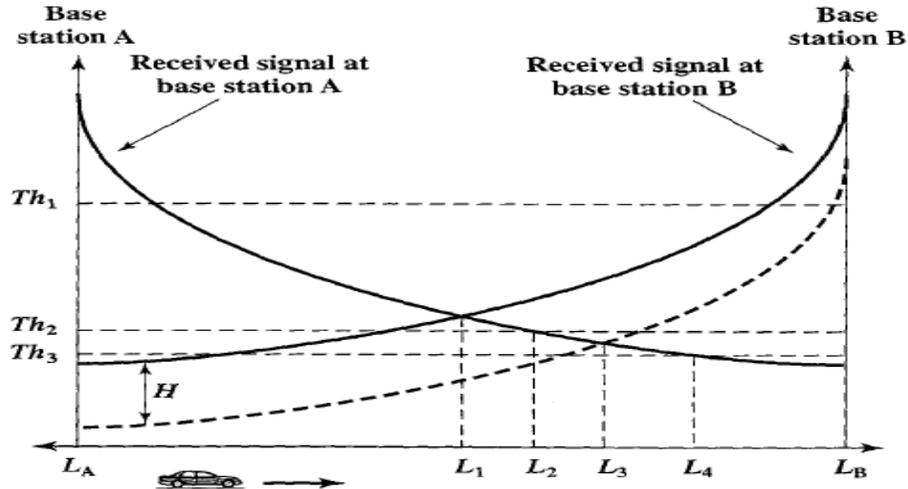


Figure 2: Handover process (Stallings, 2015)

The conventional handover is based on the comparison between Received Signal Received Power (RSRP) of serving base station and that of target base station. The handover process is initiated with the condition as shown in equation 1 (Goyal & Kaushal, 2019). This equation explains the relationship between the received signal strength of the serving cell and that of the target cell.

$$RSRP_t = RSRP_s + HM \quad (1)$$

where:

$RSRP_t$ is Reference Signal Received Power for the target base station.

$RSRP_s$ is Reference Signal Received Power for the serving base station.

HM is Hysteresis Margin (Goyal & Kaushal, 2019).

2.2.3 Vertical Handover (VHO) phases in LTE (Goudarzi *et al.*, 2015) are:

- i. Handover Initiation: In this phase, mobile terminal makes the necessary measurements used for handover initiation to a new access point (AP)
- ii. Handover Decision: This is the core step of every handover process. This is where the measurement results obtained from handover initiation are compared with predefined values to decide whether to handover or not
- iii. Handover Execution: This is where the actual handover process takes place. This is where the mobile node switches from its current network connections to the best available base station

3.0. Proposed Scheme

In this section, we describe the proposed adaptive handover decision technique to address handover problem based on mobility scenarios. This algorithm reduces handover ping pong probability and also maximizes the spectral efficiency of the system. The framework of LTE-Advanced are used for evaluating the proposed algorithm.

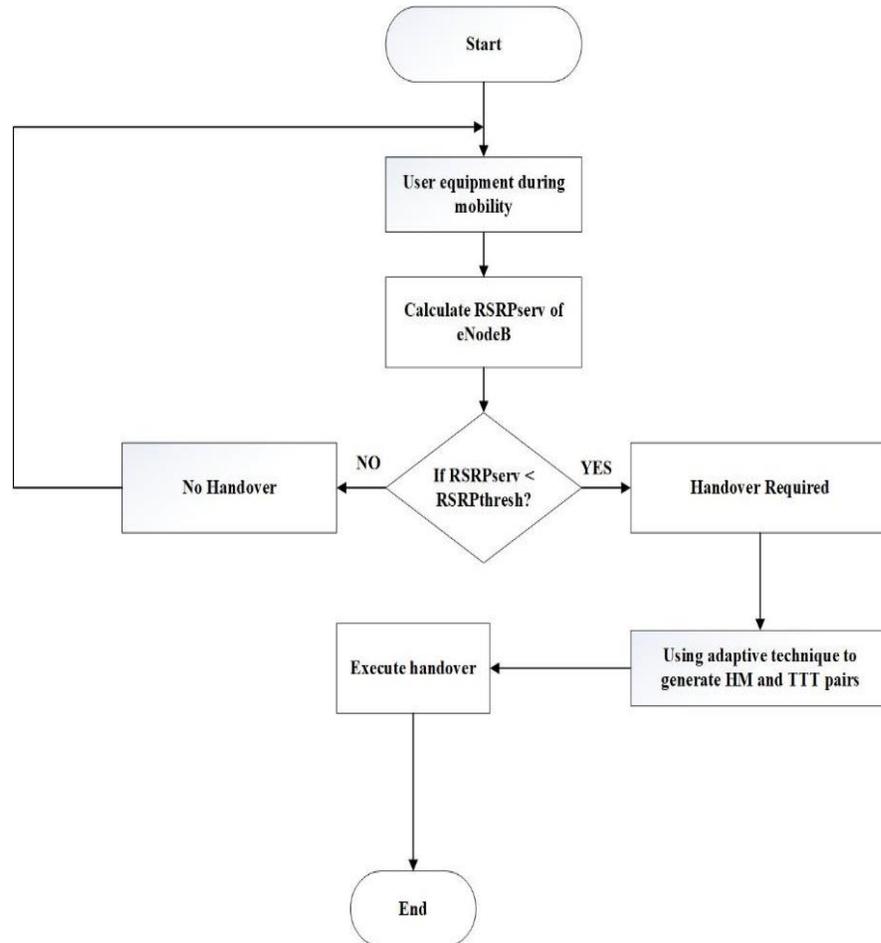


Figure 3: Proposed Scheme

3.1 Adaptation of Hysteresis Margin (HM)

The conventional handover decision is based on comparison between the received signal received power(RSRP) of the target eNodeB and that of the serving eNodeB. Handover is initiated when the RSRP of the target eNodeB exceeds that of the target eNodeB by at least a hysteresis margin (HM) level. This is shown in equation 1. The purpose of HM is to avoid the continuous handover between two eNodeBs (Silva, et al., 2018).

$$RSRP_{target} = RSRP_{serving} + HM \quad (1)$$

where

$RSRP_{target}$ is received signal received power of the target base station which is measured in dBm

$RSRP_{serving}$ is received signal received power of the serving base station which is measured in dBm.

HM is the hysteresis margin which is measured in dB

In equation 1, the HM is not dependent on user equipment's distance away from the base station. The adaptive technique is based on the modification of the actual HM based on distance of the user equipment

away from the base station. This is shown mathematically in equation 2. The equation further shows the relationship between hysteresis margin and distance between serving cell (SC) and User Equipment (UE) (Zhang, 2018)

$$HM_{adaptive} = \text{Max}\{HM_{max} \times \left(1 - \frac{d}{R}\right)^4 ; 0\} \quad (2)$$

where:

HM_{max} is the maximum hysteresis margin measured in dB (This value can be set up only at the middle of the eNodeB)

HM_{min} is the minimum hysteresis margin measured in dB (This value can be set up only at the edge of the eNodeB). This value is set up at zero because that is the minimum standard value for the parameter

d is the distance between the serving eNodeB and the user equipment

R is the distance between the target eNodeB and user equipment

α is adaptive co-efficient which is set at the default of 4 so as to minimize path loss effect (Zhang, 2018)

The parameters d and R cannot be easily determined by the network or the user equipment. This research proposes to replace these parameters by other parameters that can be used more effectively.

The path loss model describes the relationship between path loss and the distance of a user equipment away from the base station as shown in equation 3 (Becvar & Mach, 2010)

$$PL(d) = X(f) + N \log_{10} d \quad (3)$$

where

$X(f)$ shows the dependence of path loss model on frequency

N is the path loss exponent with the value of 4 for outdoor environment

The level of received of received signal at a specific distance depends on path loss and transmission power which is defined in equation 4 (Becvar & Mach, 2010)

$$RSSI(d) = P_{tx} - PL(d) \quad (4)$$

where

P_{tx} is the transmission power

$RSSI(d)$ is the received signal strength indicator

Long Term evolution advanced (LTE-A) takes into consideration basically received signal received power (RSRP) which is an essential standard used in orthogonal frequency division multiplexing (OFDM). This parameter can be used to provide the accurate measurement for a signal power for handover decision in LTE Advanced. This is replaced with the RSSI used in equation 4

RSS is then replaced with RSSI in equation 4 in this research to generate equation 5

$$RSS(d) = P_{tx} - PL(d) \quad (5)$$

Furthermore, the distance d can be written as an exponential function based on equations 3 and 5 as shown in equation 6

$$P_{tx} - (X(f) + N \log_{10} d) = RSS$$

$$d = 10^{\frac{1}{N}(P_{tx} - X(f) - RSS)} \quad (6)$$

Considering equation 6, equation 2 can be modified

$$HM_{adaptive} = \text{Max}\{HM_{Max} \times \left(1 - \frac{10^{\frac{1}{N}(X(f) + RSS - P_{TX})}}{10^{\frac{1}{N}(X(f) + RSS_{min} - P_{TX})}}\right)^4; 0\} \quad (7) \quad \text{This}$$

can be further simplified in equation 7 assuming same frequency and transmitted power for both serving and target cells.

$$HM_{adaptive} = \text{Max}\{HM_{Max} \times (1 - 10^{\frac{1}{N}(RSS - RSS_{min})})^4; 0\} \quad (8)$$

where:

RSS is received signal strength

RSS_{min} is minimum received signal strength. This corresponds to the cell radius and the RSS level at which user equipment is able to receive data

The total received signal strength has to be related to the difference between the maximum and minimum RSS observed in the area. Thus the modified adaptive HM level is defined mathematically shown in equation 9

$$HM_{adaptive} = \text{Max}\{HM_{Max} \times \left[1 - 10^{\frac{1}{N} \left(\frac{RSS_{act} - RSS_{min}}{RSS_{min} - RSS_{max}}\right)}\right]^4; 0\} \quad (9)$$

where

RSS_{act} is the actual received signal strength which can be easily measured during user equipment operation

RSS_{max} is the maximum received signal strength. It utilizes the data gotten from previous RSS values in the area reported by the user equipment.

RSS_{min} is the lowest received signal strength at which UE will still be able to receive data.

The handover control parameter values (Hysteresis Margin(HM) and Time To Trigger (TTT)) are selected according to (3GPP, 2017), in which HM and TTT possess the values on Table 1

Table1 Pair of Values for the modified adaptive HM and TTT

HMmod-adp (dB)	4.1	20.3	12.8	22.3
TTT(ms)	128	256	320	512

Handover Ping Pong Probability(HPPP): This occurs when the Mobile Station is handed over from one cell to another but quickly handed back to the original cell under a time period that is less than the critical ping-pong interval T_c . HPPP is an important metric that calculates the frequency of unnecessary handovers between two adjacent cells. Some of the factors that affect this ping pong handover include speed, time to trigger and hysteresis margin.

Handover Ping Pong Probability is mathematically shown in equation 10 (Alhammedi *et al.*, 2018)

$$HPPP = P_r(T_i \leq T_c) \quad (10)$$

$$T_i = T_l - T_{hb}$$

where

T_i is the time passed by the UEs starting from initiating handover in eNodeB and its return to the same eNodeB

T_c is the critical ping-pong interval. It is defined as a short time period (which is assumed to be 2 s) required to calculate the number of unnecessary handovers between neighboring cells.

4. Results and Discussion

The developed architecture consists of 19 eNodeBs each with a radius of 1km. User equipment moving from one eNodeB to another eNodeB with varying speeds of 3km/h, 30km/h and 120km/h. Random Mobility model was employed and handover ping pong probability(HPPP) as the performance indicator. The simulation results derived are dependent on inter site distance, TTT and UE's velocity. Based on the selected values of TTT, the probability functions are changing with respect to inter-site distance

Figure 4 shows the HPPP at 3km/h, 30km/h and 120km/h based on different TTT values of 128, 256, 320 and 512 (ms). It can be observed that HPPP at TTT values of 256ms and 512ms was 0 which indicates a negligible impact of ping pong at all the three different velocities. At same velocities of 3km/h, 30km/h and 120km/h, the HPPP are 0.15 and 0.14, 0.13 and 0.13 then 0.15 and 0.14 at 128ms and 320ms respectively. This low values of HPPP indicates the minimal level of call dropping and eventually the degradation of the network performance. Figure 5 shows the comparison between the proposed technique using adaptive control and the conventional technique based on Q learning. The result showed improvement of 29%, 28% and 13% at 3km/h, 30km/h and 120km/h respectively as compared to the work of Goyal & Kaushal (2019). This shows that the improvement in handover ping pong probability using the proposed technique as compared to Q learning.

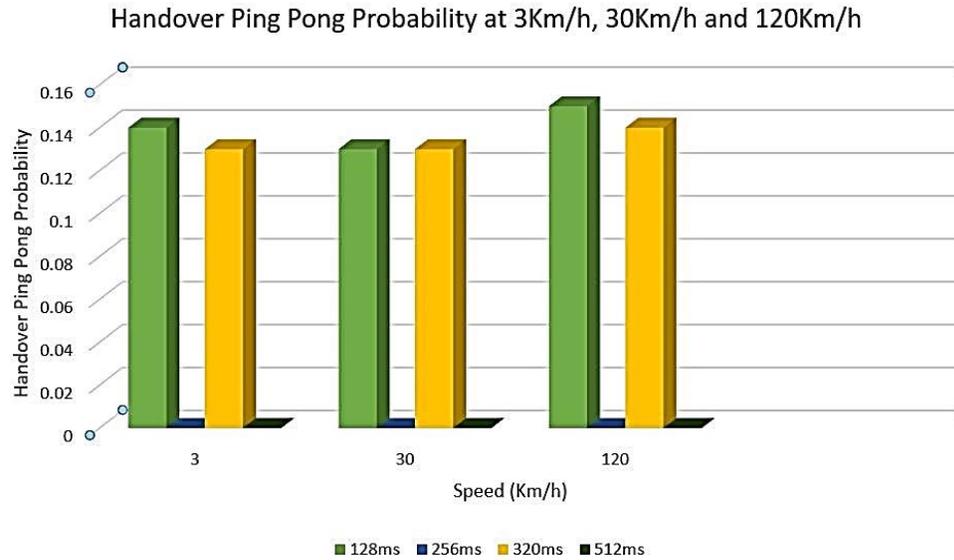


Figure 4: Handover Ping Pong Probability

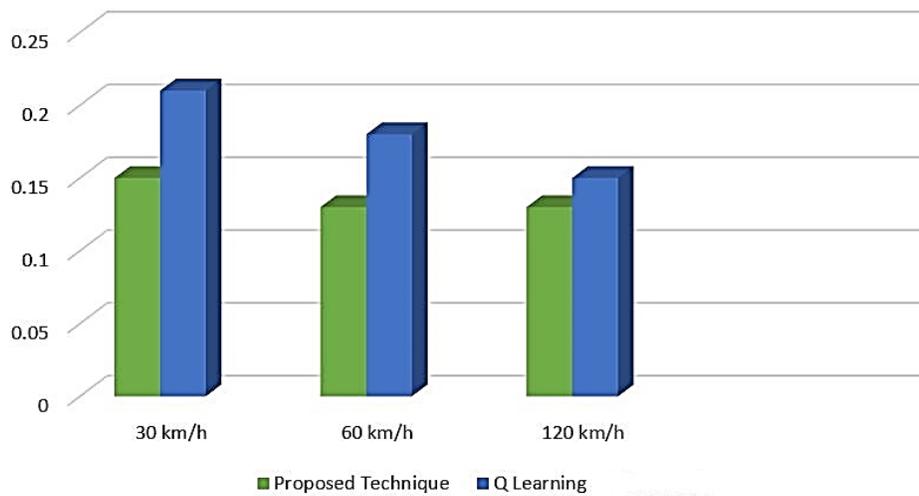


Figure 5 Handover Ping Pong Probability

4. Conclusion

The developed handover decision scheme using adaptive based technique at 3km/h, 30km/h and 120km/h achieved an improvement of 29%, 28% and 13% reduction in handover ping pong probability respectively as compared to the conventional technique. These results obtained will lead to decrease in call dropping and also degradation of network performance. Researchers can further extend this work by incorporating energy



efficient mechanism with guaranteed quality of service requirements such as battery consumption and packet loss during handover.

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