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Review of Handover Decision Algorithms in Wireless Communication Systems

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Abstract

Handover is one of the key components in cellular network mobility management. This is as a result of growing consumer demand for access to communication services anywhere and anytime. The flexibility offered by IEEE and 3GPP standards in system designs of IEEE 802.16m, 4G and 5G networks make it possible through handover decision algorithm for a mobile user to establish a seamless connection while simultaneously guaranteeing acceptable quality of service across the different RATs. This paper presents a review of the various handover decision algorithms and their analyses conducted for suitable applications in the mobile communication systems.

Keywords: *Handover, IEEE, 3GPP, RAT, 4G, 5G*

Introduction

Handover is a process in communications in which a connected cellular call or a data session is transferred from one cell site (base station) to another without disconnecting the session. Cellular services are based on mobility and handover, allowing the user to be moved from one cell site range to another or to be switched to the nearest cell site for better performance (Shayea 2012). In Long Term Evolution–Advanced Network (LTE-A), for example, the current base station or enhanced Node B (eNB) where the User Equipment (UE) is connected is referred to as the serving eNode B while the eNode B where the UE is to be transferred during handover session is called the target eNode B. Handover can be classified as either horizontal or vertical. Horizontal also referred to as intra-technology handover is the handover that occurs within a system of the same technology, for example the handover within LTE-A system of Third Generation Partnership Project (3GPP) technology. Vertical usually referred to as inter-technology handover is the handover between different Radio Access Technologies (RATs) like the handover between LTE-A and Wireless Fidelity (WiFi) networks which were developed by 3GPP and Institute of Electrical and Electronics Engineers (IEEE) standards respectively (Abubakar, 2014). The remainder of this paper is organized as follows: Section II discusses the background on handover decision algorithm; section III review of handover decision algorithm is presented. Comparative analyses of the reviewed algorithms are conducted in section IV and finally conclusion is drawn in section V.

Background of Handover Decision Algorithm in Mobile Communications

The present wireless network integrates different access networks like cellular network, wireless local area network; metropolitan area network and personal area network all are capable of providing enhanced services to mobile users. In such converged systems, the seamless and efficient handoff between different access technologies (vertical handoff) is essential. Vertical Handover Decision algorithms widely employed in cellular systems, which use a threshold comparison of one or more specific metrics such as received signal strength (RSS), carrier-to-interference ratio (CIR), signal to interference and noise ratio (SINR), and bit error rate (BER) to trigger a handover decision process. In most of the studies RSS is used as the main handover decision criterion. The handover algorithm must be able to guarantee acceptable quality of service (QoS), improved spectral efficiencies and throughputs (Jyotsna *et a*l. 2012). Table I shows the basic handover decision metrics for RSS-based handover decision algorithm (Shreedhar and Vinay 2017)

***Table I:* Standard LTE-A HO Measurement Events**

Event Type	Description
Event A1	Serving cell strength becomes better than certain threshold

Event A2	Serving cell strength becomes worse than certain threshold
Event A3	Neighbor cell strength becomes offset better than serving cell
Event A4	Neighbor cell becomes better than certain threshold
Event A5	Serving cell becomes worse than threshold1 and neighbor cell becomes better than threshold 2
Event A6	Neighbor cell offset becomes better than serving cell
Event B1	Inter RAT neighbor cell becomes better than certain threshold
Event B2	Serving cell becomes worse than threshold1 and inter RAT neighbor cell becomes better than threshold 2

Reviews of Handover Decision Algorithms in Mobile Communications

The following paragraphs discuss some reviewed handover decision algorithms.

Pollino (1996) and Roy (2009) have stated in their works about Handover Decision Algorithm (HODA) based on received signal strength known as handover decision algorithm-received signal strength (HOD-RSS). It is based on the principle of a Handover (HO) is triggered when the RSS of the target channel (eNB) is greater than the RSS of the serving by some handover margin level M_{RSS} in dB as shown in equation 1.

$RSS_T > RSS_S + M_{RSS}$ ---- (1)

The HO algorithm is taken based on a single system's metric RSS.

A HO decision algorithm based on UE's distance (D) from base station (eNB) and relative received signal strength (HOD-D-RSS) in log-normal fading environment has been presented. The algorithm has two system metrics, namely; distance and received signal strength. HO process is triggered whenever these two conditions are met. The first condition is that the distance between the user (UE) and the target eNB is less than the distance between the user and the serving eNB by a certain threshold distance (γ_d) in meters. The second condition is that the average RSS_T of the target eNB (cell, sector) is greater than the RSS_S of the serving eNB by a given hysteresis level, (M_H) (Shayea 2014, Itoh 2002). The conditions of the algorithm are shown in equation 2

$$\left.\begin{aligned} Dis_T &< Dis_S + \gamma_d \\ RSS_T &> RSS_S + M_H \end{aligned}\right\} \quad \ldots (2)$$

Yang *et al.* (2007) and Jyotsna *et al.* (2012)) have stated in their works about handover algorithm based on Signal interference to noise ratio (SINR) known as handover decision algorithm - signal interference to noise ratio (HOD-SINR). In this case the handover is initiated when the target SINR ($SINR_T$) is sufficiently better than the SINR of serving ($SINR_s$) channel by certain hysteresis margin level M_{SINR} as shown in equation 3.

$$SINR_T > SINR_S \quad --- (3)$$

Shayea *et al.* (2014) developed an adaptive handover decision algorithm based on SINR with handover hysteresis, threshold, and resource availability and was shortened as multi-influence handover decision algorithm (MIF-HODA). The work was presented based on whether the HO was for changing the primary component carrier (PCC) or changing serving sector/eNB. The HO algorithms were respectively represented as

$$\left.\begin{aligned} SINR_{S\_PCC} &\leq M + \gamma \\ SINR_{T\_PCC} &> SINR_{S\_PCC} + M \end{aligned}\right\} \quad \ldots (4)$$

and

$$\left.\begin{aligned} &ASINR_{T\_PCC} > ASINR_{S\_PCC} + M),\ SINR_{T\_PCC} > \gamma, && \text{if } L_S \geq L_T + LM \\ &SINR_{T\_PCC} > M + \gamma, && \text{if } L_T \geq L_S + LM \end{aligned}\right\} \quad - (5)$$

Where *M* is the handover hysteresis, γ the threshold levels, *A* the average, *L* the resource Loads availability, *LM* = Resource Loads Margin level, subscripts s and T for serving and target cells respectively.

The performance evaluation has shown remarkable improvement in terms of spectral efficiency close to eNBs and low outage probability..

Ali *et al.* (2011) presented two HO algorithms called semi-soft (SSHO) and fractional soft HO (FSHO) algorithms. In FSHO, the VoIP service was simultaneously being transmitted by UEs and eNBs while non VoIP service was selectively transmitted by either the eNB or UE. The UEs constantly sent measurement reports to the serving eNB where HO decisions were taken based on the measurements. The SSHO algorithm employed the site Selection Diversity Technique (SSDT) by allowing UEs to receive information only from selected eNBs and during HO process each UE keeps multiple control signals while the signal of user data is selectively done by an eNB with the highest pilot signal. The outage probability was evaluated as the means of performance measurement. Although it showed low outage probability, cell interference was completely ignored.

Saeed *et al.* (2016) has implemented a type - II fuzzy logic algorithm that was aimed at minimizing HO rate, maximize throughput, and minimize system delay for UEs moving at 10, 60 and 120 km/hr. respectively. The system metrics used were the average HO per UE per second, system delay and throughput. The result showed low HO failure rate, minimum delay and increased in total system throughput.

There are other spectrum HO techniques in literature like the partial frequency reuse and soft handover (PFR SHO) which has been proposed to mitigate inter-cell interference problem (Chiu and Huang, 2010). The basic idea was to dynamically select between partial frequency reuse scheme and soft handover scheme to provide better quality of service to cell-edge users.

Comparative Analyses of the Reviewed Algorithms

Table II showed comparative analyses of the reviewed HODA algorithms for mobile communications

Table II: Comparative of the reviewed HO decision algorithm

Author(s)'s Name/ Date	Handover (HO) Algorithm (technique)	System Metric used	Description of scheme	Advantages	Limitations
Shayea *et al.* (2014) and Roy (2009)	HOD-RSS	RSS	Dynamic measurement of RSS of the serving and target eNBs and comparing with HO margin value. HO is triggered when the RSS of the target channel (eNB) is greater than the RSS of the serving by some handover margin level M_{RSS} in dB	1.Simplicity and low computational cost. 2.Reduces false HO initialization. 3. Good for intra system with uniform power scheme. 4.Can combined with other system metrics 5. Easy assessment of link realiability.	1.Ping-pong problem with low RSS 2.cannot be alone for link QoS and reliability 3.Affect HO for data associated signal

Shayea *et al.* (2014) and Itoh et al. (2002)	HOD-D-RSS	RSS D	HO triggered if (1) the distance D between the user (UE) and the target eNB is less than the distance between the user and the serving eNB by a certain threshold distance (γ_d) in meters and (2) the average RSS_T of the target eNB (cell, sector) is greater than the RSS_S of the serving eNB by a given hysteresis level, (M_H)	1.Prevent unwanted HO 2.mitigate shading effect 3.Lower outage probability compared to RSS scheme	1.Distance estimate error for spreaded UEs 2.Ping-Pong effect
Yang (2007), Jyotsna (2012) and Shayea (2014)	HOD-SINR	SINR	Handover is initiated when the target SINR ($SINR_T$) is sufficiently better than the SINR of serving ($SINR_S$) channel by certain hysteresis margin level M_{SINR} a	1.Good throughput compared with RSS 2.Adapt to difficult condition like noise	1.Ping-Pong due excess HO 2. Cannot alone suffice guaranteeing QoS
Shayea (2014)	MIF-HODA	SINR with M, γ and L	It is an adaptive handover decision algorithm based on dynamic computation of SINR with handover hysteresis, threshold, and resource availability.	1Improved SINR from users' perspective. 2.spectral efficiency close to eNBs 3.low outage probability 4Improved system throughput compared with single parameter HODAs	1.High cell edge spectral inefficiency 2. Optimal resource allocation with interference management schemes required to improve overall system throughput 3. Coverage limitation

Ali *et al.* (2011)	FSHO	RSSI, SINR,	The UEs constantly send measurement reports to the serving eNB where HO decisions are taken based on the measurements.	1.Reduce data loss 2.low disruption time 3.Reduced outage Probability.	1.HO overhead due to many control signaling. 2.Cell-edge high spectral inefficiency
Ali *et al.* (2011)	SSHO	RSSI, SINR	UEs receives information from only those eNBs listed in the diversity set but communicate only with the anchored eNB.	1.Reduce data loss 2.low disruption time 3.Reduced outage Probability 4. Interference mitigation.	1.computational burden 2.HO overhead due to many control signaling. 3.Cell-edge high spectral inefficiency
Saeed *et al.* 2016)	FL2LH HO	RSRP	Dynamic usage of Mandami type 2 fuzzy logic with inputs to compute average HO rate and system throughput.	1.Better performance than the Fuzzy type 1 2. Fast decision being an AI 3.User Satisfaction (QoS)	1.increased complexity 2.comparably high latency
Chiu and Huang (2010)	Hybrid PFR and SHO	Bandwidth SINR	Flexible Bandwidth allocation according to cell-load by using combined PFR and SHO	1.Data rate allocation fairness 2.improved cell edge spectral efficiency 3.Link reliability improvement.	1.Resource wastage at cell edge 2.High latency 3.Possible Ping-Pong effect.

Conclusion

The handover decision algorithms for mobile communications were reviewed and the comparative analyses conducted. From theses analyses, one can conclude that algorithms with combined system metrics could offer enhanced system performance in terms of systems' throughput, spectral efficiencies, low outage probability and seamless connection.

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