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Review of Handover Decision Algorithms in Wireless Communication Networks

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Abstract: *Handover is a process in mobile 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 allows the user to be moved from one cell site or another for better network performance. There are many handover decision algorithms presented in literature. Generally, system metrics or network parameters are used as measure to decide whether or not to invoke a handover process. For wireless communication networks, the 3GPP and IEEE usually set minimum threshold level that when satisfied would initiate handover process from serving cell to the target cell. It is left to the system engineers to develop their own algorithms based on the network peculiarities to maintain and enhance the network key performance indicators (KPIs). Toward this direction, this paper is focused on reviewing the handover decision algorithms for wireless communication network highlighting the system metrics used and the area of applications.*

Keywords: UE, 3GPP, IEEE, KPI, Handover

I. INTRODUCTION

Mobility is a one of the key features of wireless cellular systems that enables the Users Equipment (UE) (also called mobile stations) to change seamlessly, through handover processes, their point of attachments while using their data and voice services. Handover in wireless communication is a procedure to transfer a UE session from a source evolved NodeB (eNB) to a target eNB. The handover process is adaptive in nature where the UE periodically reports system metrics to the eNBs or Mobility Management Entity (MME) for decision making depending on whether the signaling is through X2 or S1 protocol respectively ([1], [2], [3])

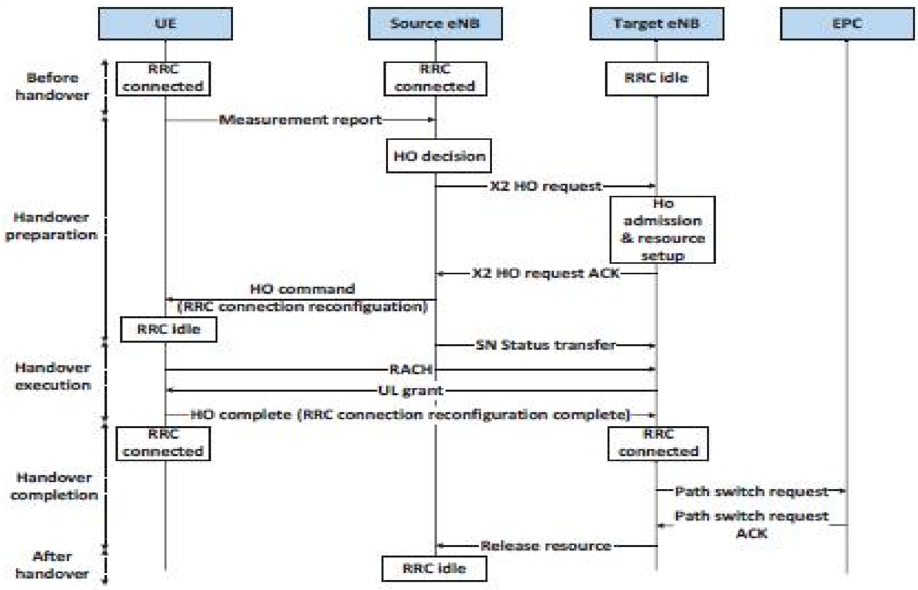


Fig. 1: X2 Handover Interface Process (Source: [1])

There have been gradual changes over the years in the architecture, deployment and implementation of handover processes for wireless communication. For example, the Universal Mobile Telecommunications System (UMTS) technology supported the Radio Network Controller (RNC), a network component that was in charge of handling any handover signaling capability whereas in LTE-A the RNC in the Evolved Packet System (EPS) has been removed and the intelligence is kept in the eNB side that is responsible for handover through X2 interface. The eNBs perform all the handover activities through the X2 interface. The X2 procedure can be described in five steps, as shown in Fig. [1]

Explanation of the procedures of Figure 2

1) Before Handover: UE is attached to the source eNB. The Dedicated Radio Bearers (DRBs) and Signaling Radio Bearers (SRBs) are established and uplink/downlink (UL/DL) traffic is transmitted between the source eNB and the UE. The UE remains in the Radio Resource Control (RRC)-Connected, states with respect to the source eNB, and keeps all the resources allocated it

2) Handover Preparation: UE sends the periodical measurement report to the source eNB; this report contains information about the neighboring cells. The source eNB triggers the handover based on the Measurement and chooses the best reported target cell by the UE. Then, the source eNB sends a X2 handover request to the target eNB. This message contains the information needed to perform the handover (e.g., UE context information, Radio Access Bearer (RAB) context, Target Cell ID). Considering the QoS in the RAB context, the target eNB performs call admission control and if it is able to provide the requested resources for the new UE, it sends a handover (HO) request acknowledgment (ACK) to the source through the X2 direct tunnel setup (i.e., handover is eNB accepted). In the RRC message, physical layer parameters are provided to the UE in order to be synchronized with the target eNB. Finally, the source eNB sends the HO command message that encloses the RRC. Connection Reconfiguration message to the UE. If the target eNB cannot accept the Ho request (due to load or the required setup), it responds to the source eNB with an X2 failure message. During this step, the UE states remain unchanged.

3) Handover Execution: UE receives the RRC Connection Reconfiguration message and transits to the RRC idle state triggering the detachment from the source eNB. The source eNB sends the Sequence Number (SN) status transfer message that contains information to the target eNB through X2 interface. For UL the first missing data unit is included and for DL the next sequence number to be allocated. Then, UE is synchronized with the target based on the given parameters and send the HO Confirm message that encloses the RRC Connection Reconfiguration Complete to acknowledge the successful handover to the target eNB. As a result, the UE transits to the RRC connected state with respect to the target eNB. Concerning the UE synchronization, if a dedicated random access preamble has been received in the RRC Connection Reconfiguration message, the UE does not need to perform the random access procedure, i.e., contention free Random Access Channel (RACH) process. If this is not the case, the UE performs the normal random access (RACH) procedure

4) Handover Completion: The target eNB receives the RRC Connection Reconfiguration Complete message and the path switch procedure is initiated between the target eNB and the MME/S-GW. The target eNB starts to forward all the packets received from the X2 interface to the UE before any new ones coming from the Serving Gateway (S-GW) (i.e., target eNB receives the end-marker from the old path switch and starts transmitting packets from the new path switch). Afterwards, the source eNB UE context is released via receiving UE release context message from the target eNB . Finally, the S1 bearer that was initially established between source eNB and UE is also released.

5) After Handover: UE is attached to the target eNB. The DRB and SRB are established and UL/DL traffic is transmitted as in the initial step.

In this paper, a review of handover decision algorithms in wireless communications has been presented. The remaining pat of the paper is organized as follows, the reviews of related works are discussed in Section II, comparison of the different algorithms is dealt with in Section III, discussions are made in Section IV and finally, the conclusion is drawn in Section V.

II. REVIEW OF RELATED WORKS

[4] developed an adaptive handover decision algorithm popularly known as the Multi-Influence Factor Handover Decision Algorithm (MIF-HODA) which was based on SINR, resource load availability and handover hysteresis

margin for an LTE-A network environment using carrier aggregation (CA). It was adaptive as a result of location-aware of UEs at any time by sending periodic measurements to the eNBs. In this work, the handover process was initiated when the target eNB (T) has more radio resources available than the serving eNB (S) by resource Loads Margin level (LM), as well as the Average SINR of the target eNB (T) is greater than the serving with hysteresis (M) and threshold levels (γ) as shown in equation (1)

$$\left.\begin{array}{ll} ASINR_T > ASINR_S + M,\ ASINR_T > \gamma, & if\ L_S \geq L_T + LM \\ A\,SINR_T > M + \gamma, & if\ L_T \geq L_S + LM \end{array}\right\} \quad \text{--- (1)}$$

Where M is the handover hysteresis margin, γ the SINR threshold level, $ASINR_T$ average SINR of the target eNB, $ASINR_S$ the average SINR of the serving eNB, L_S the resource loads availability of serving eNB, L_T resource loads availability of target eNB and LM is the resource loads margin level. The system model consisted of 61 macro-hexagonal eNBs layout model with 500 meter inter-site-distance. System level simulation was conducted and the performance analysis was done by comparing the proposed MIF-HODA with legacy handover algorithms based on RSS, RSS-D and HODA-SINR. The result of the network performance evaluation showed remarkable improvement in terms of cell edge spectral efficiency of mobile users AS shown in Fig. 2

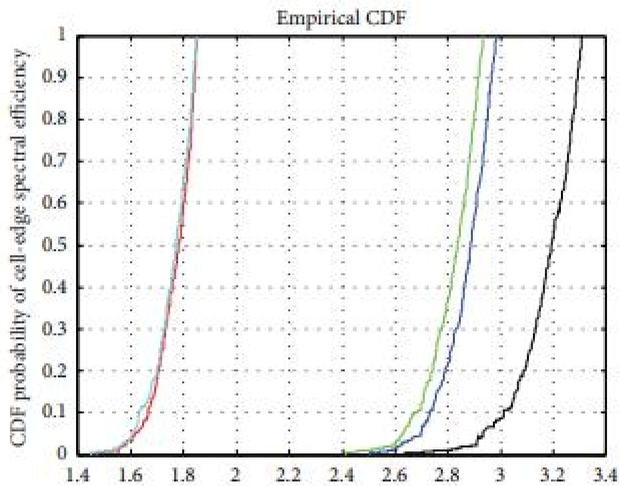
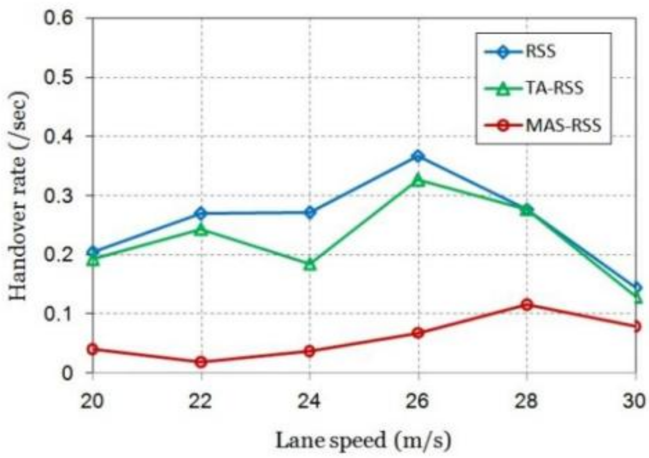


Fig.2: Cell Edge Spectral Efficiency



Fig, 3: Handover Rate with Speed

[5] has presented a handover decision algorithm to reduce handover rate in Vehicle to Vehicle (V2V) communication. The algorithm used Moving Average Slope Received Signal Strength (MAS-RSS) and SINR as system metrics for handover decision making. The MAS-RSS observed the dynamics of RSS and could initiate handover adaptively when the moving average RSS and the SINR were below threshold values. By this process the connection was maintained

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regardless of measured RSS and therefore the number handover rates were reduced. The simulations of vehicle mobility and V2V handover were done by Simulation of Urban Mobility (SUMO) and MATLAB tools respectively. The simulation results showed that the proposed algorithm presented reduced number of handovers when compared with the other RSS-based algorithm as displayed in Fig. 2

[6] developed vertical handover decision algorithm with three Radio Access Technologies (RATs) namely; LTE –A, mm Wave (5G) and the Dedicated Short Range Communication (DSRC). The HODA was based on Q-learning with speed of a vehicle and the RSS taken as decision system metrics. The Objective Modular Network Tested in C++ (OMNeT++) and Simulation of Urban Mobility (SUMO) tools were used in the simulation. The results of the proposed algorithm were compared with the Technique of Order Preference by Similarity to Ideal Solution (TOPSIS) for performance evaluation. The KPIs evaluated amongst others were the handover success probability and number handover failures. The proposed Q-learning based algorithm presented handover success probability of 0.6 as against TOPSIS-based algorithm which gave 0.45 for 50 handover attempts as shown in Fig 4. Similarly, the Q-learning and TOPSIS displayed 6 and 8 respectively as the number of handover failures at the speed of 40 m/s as displayed in Fig.5. These showed performance improvement in favour of the proposed Q-learning based handover decision algorithm.

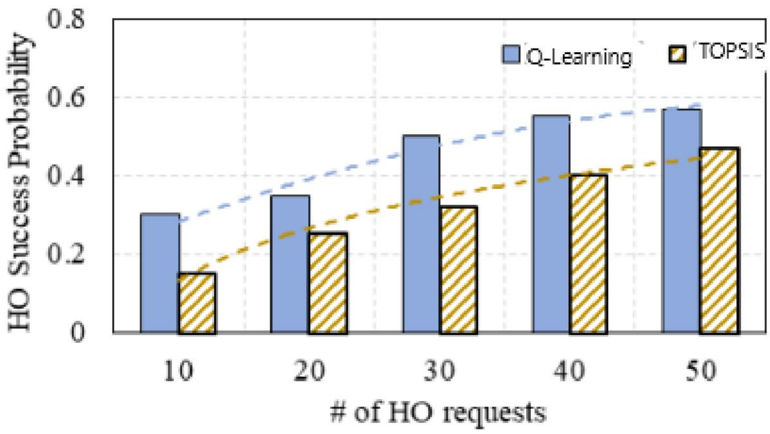

Fig.4: Handover Success Rate

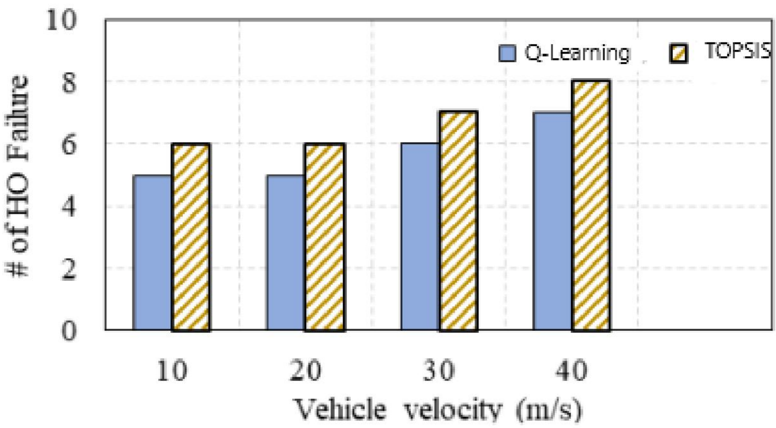

Fig.5: Handover Failure Rate

[7] implemented an adaptive handover algorithm based on elliptic function and random suppression in high-speed railway in Long Term Evolution –Railway (LTE-R) communication network. The decision system metrics used were hysteresis threshold and the train speed. MATLAB simulation tool was used. The validation of the proposed algorithm was done by performance comparison with the conventional (legacy) RSS- based algorithm in terms of handover success rate and so on the result of the handover success rate versus various speeds is shown in Fig. 6 The simulation

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results showed that the proposed algorithm presented an improved handover success rate in comparison with the RSS based algorithm.

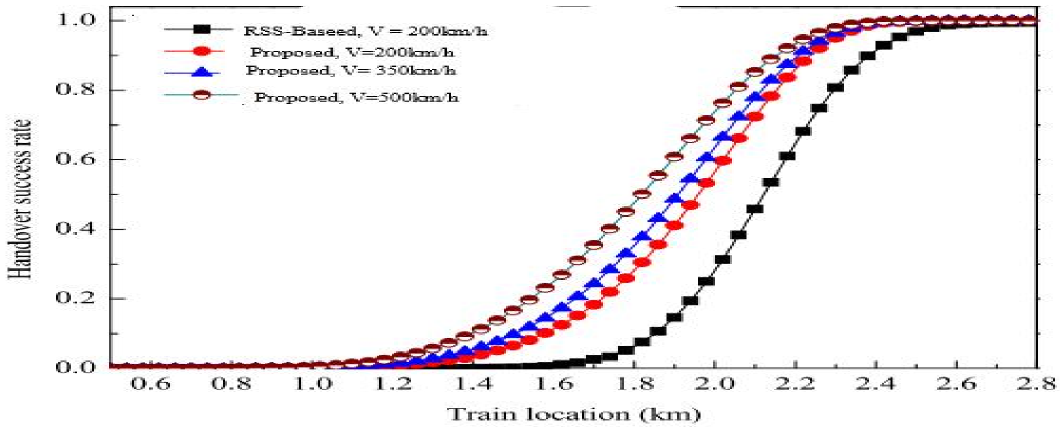

Fig. 6: Handover Success Rate versus Train Speed

[8] developed a Fuzzy Logic (FL) based handover decision algorithm for 5 G network using Handover Margin (HOM) and Time To Trigger (TTT) as decision system metrics. This FL-based handover algorithm with Dynamic HOM and Dynamic TTT (FLDHDT) was implemented using *ns*-3 simulator. The KPIs considered during this simulation were the number of handovers, overall system throughput, and ping-pong ratio. The result showed that the proposed FLDHDT based HODA demonstrated performance improvement in the KPIs considered when compared with the conventional algorithm based on RSS (also called Event A3) only and the FL-based handover scheme with dynamic adjustment of only HOM (FLDH) handover decision algorithms. For example, for the overall system throughput within the service of 15 eNBs, the proposed FLDHDT, the Conventional and the FLDH showed values of 443.2 Mbps, 387.7 Mbps and 419.7 Mbps respectively as presented on Fig. 7. Similar argument could be deduced from the result of the other KPIs. Therefore, the FLDHDT substantially improved the handover performance of 5G ultra dense network.

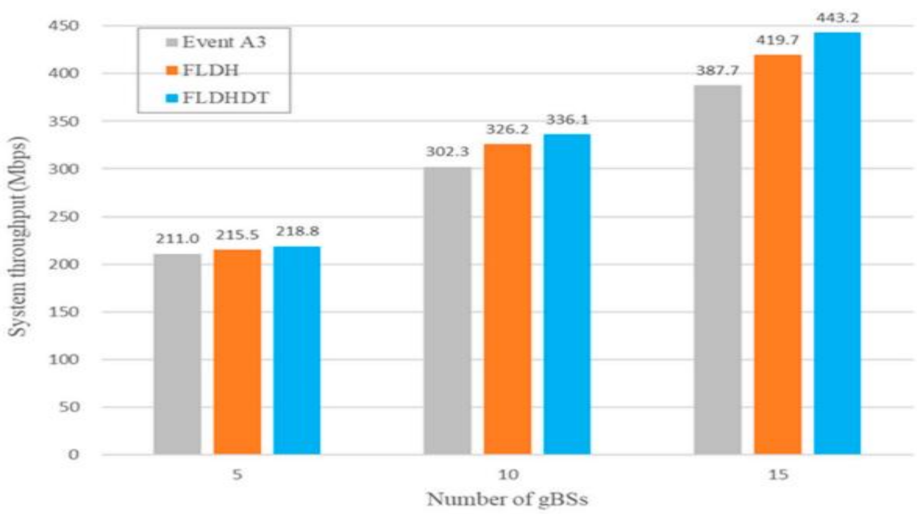

Fig. 7: System Throughput

[9] proposed algorithm Handover Decision Algorithm (HODA) using Spectrum Aggregation Deployment (SAD) scenario of Licensed LTE-A spectrum with LTE-A in TVWS spectrum (abbreviated as Proposed-TVWS) in conjunction with other system metrics. The handover from the Serving to the Target eNB was initiated when equation (2) is satisfied. The Primary Component Carrier (PCC) with signalling information belonged to the LTE-A network while the Secondary Component Carrier (SCC) served from the TVWS spectrum.

$$ARSRP_T > ARSRP_S + M,\ ARSRP_T > \gamma, \quad if\ L_S \geq L_T + LM \quad \} \qquad \text{--- (2)}$$

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Where , γ the $RSRP$ threshold level, $ARSRP_T$ the average $RSRP$ of the target eNB, $ARSRP_S$ the average $ARSRP$ of the serving eNB, L_S the resource loads availability of serving eNB, L_T resource loads availability of target eNB and LM is the resource loads margin level. Fig. 8 shows the result of radio link failure rate when the proposed algorithm is compared with the conventional (CONV) and the Multi-Influence Factors (MIF) handover decision algorithms.

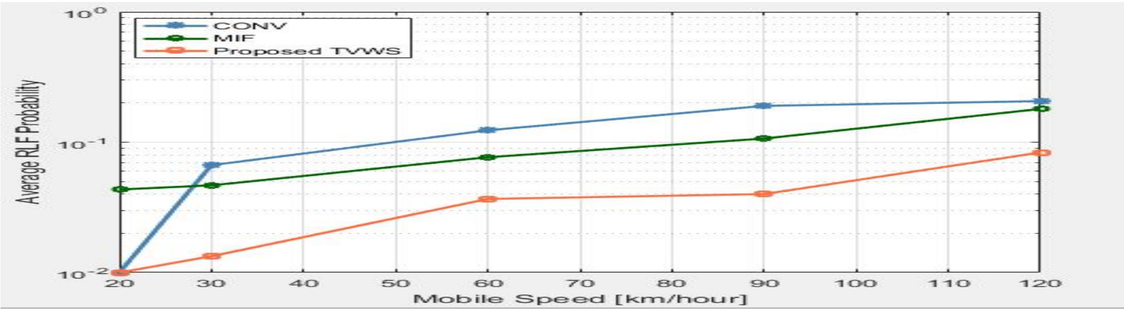

Fig. 8: Average Radio Link Failure Rate

III. COMPARISON OF THE DIFFERENT ALGORITHMS

This subsection present comparison of the various handover decision algorithms discussed

Table I: Comparison of the Handover Decision Algorithm

Author(s)	Handover Decision Algorithm (HODA) Name	System Metric used	Description of scheme	Applications
[4]	MIF-HODA	SINR with M, γ *and* L	It is an adaptive handover decision algorithm based on dynamic computation of SINR with handover hysteresis M, threshold γ, and resource availability L.	Used in LTE-A network with carrier aggregation with deployment in suburban areas
[5]	MAS-RSS	RSS and the SINR	The MAS-RSS observed the dynamics of RSS and could initiate handover adaptively when the moving average RSS and the SINR were below threshold values	Applications in vehicular system
[6]	Q-learning	Speed and RSS	The Objective Modular Network Tested in C++ (OMNeT++) and Simulation of Urban Mobility (SUMO) tools were used in the simulation	Vertical handover application across radio Access Technologies
[7]	LTE-R HODA	hysteresis threshold and Speed	It is an adaptive handover algorithm based on elliptic function and random	Railway Communications

			suppression in high-speed railway in Long Term Evolution – Railway.	
[8]	Fuzzy Logic (FL)based (FLDHDT)	Handover Margin (HOM) and Time To Trigger (TTT	The FL-based handover algorithm is implemented using *ns*-3 simulator	5G ultra dense network
[9]	Spectrum Aggregation with System Metrics	$RSRP$, LM, γ	Carriers from LTE-A and TVWS spectra were aggregated during the handover decision making process	Applications to less dense and rural areas

IV. CONCLUSION

A number of handover decision algorithms for wireless communications are reviewed. Their description and system metrics for handover decision making are highlighted. The application of each reviewed algorithm is mentioned. Therefore, one can conclude that the review of handover decision algorithms for wireless communication is being achieved.

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