Performance Evaluation of Enhanced Handoff in WCDMA Cellular Network Using an Intelligent Scheme

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ABSTRACT-One important measure for signalling overhead in Wide Band Code Division Multiple Access (WCDMA) is the number of handoff per unit time. In particular, the link addition and release for the soft handoff are crucial for the amount of signalling load in the network. Frequent Soft handoff cause more signalling traffic and channel utilization wastage. Therefore it is desired that handoff should be done only when it is necessary. Besides, handoff decision should be precise by taking into account all possible options and considering the best one. In this paper, a Fuzzy Logic based soft handoff decision algorithm was developed, considering the user mobility to suppress the ping-pong effect. By using GPS positioning, the developed algorithm intelligently adds a hysteresis parameter associated with distance between the mobile and surrounding base stations and a hysteresis parameter associated with the mobile heading direction in soft handoff events. The performance was verified in a MATLAB simulation by applying the developed intelligent soft handoff algorithm to a WCDMA system in Onitsha urban city. The result shows that by using the developed algorithm, soft handoff number is decreased by 33.9% compared to the traditional algorithm.

KEY WORDS; Soft handoff, signalling overhead, radio link events, Fuzzy Inference System

1.0 Introduction

Handoff refers to the mechanism by which an ongoing call or data session is transferred from one Access Point (AP) connected to a core network to another. Wide Band Code Division Multiple Access (WCDMA) cellular networks support soft handoff. Mobile stations (MSs) within soft-handoff region (SR) use multiple radio channels and receive their signals from multiple base stations (BSs) simultaneously. Soft handoff guarantees a high quality of service, enhanced communication quality and provide flexibility in the network. However, frequent soft handoffs influence the quality of service, increase the signalling overhead on the network, and degrade throughput in data communications. Conventional handoff algorithms only consider received signal strength (RSS), causing many unnecessary handoffs [1]. Especially, when MS moves in cell borders, the ranking of RSSs from surrounding BSs may vary from time to time and cause a call to be repeatedly handed off back and forth between the BSs, in what is called the “ping-pong effect”. Therefore, an efficient handoff algorithm is needed to decrease handoff number and increase system performance for cellular communication systems.

The use of fuzzy logic to develop algorithms for handoff is viable as the nature of network parameters is imprecise. In this paper, an adaptive soft handoff algorithm was developed based on user mobility to adjust handoff hysteresis parameters using fuzzy logic. The developed algorithm was applied to a WCDMA system for performance verification. The result shows that by using the developed intelligent soft handoff algorithm, the numbers of soft handoff and probability of false handoff are decreased compared to the conventional algorithm.

2.0. Review of Related Works

Over recent years, many investigations have addressed soft handoff algorithms to improve handoff performance. Some fuzzy logic-based methodologies have already been developed in literature to provide soft handoff decision. **[2]** developed a mathematical model for soft handoffs in Wideband Code Division Multiple Access (WCDMA) Network to analyze the problem of soft handoffs in cellular radio systems. The system capacity was also considered to be finite. Different performance measures like blocking probability of new calls, call dropping probability, blocking probability of handoff calls were developed. [3] developed an adaptive handoff method for parameters evaluations by applying fuzzy inference system and optimization algorithm as the existing method was based on the manual evaluation and was difficult to operate on large scale. **[4]** developed an intelligent framework for soft handoff that integrates two components: (i) machine learning methodologies: self-organizing map (SOM) and pattern classification for robust performance evaluation of available soft handoff data; (ii) multiple attribute decision making (MADM) mechanisms: the Analytical Hierarchy Process (AHP) which result feeds the Technique for Order of Preference by Similarity to the Ideal Solution (TOPSIS) for efficient access network selection. Further, AHP and TOPSIS can effectively be applied as MADM algorithms in handoff decision framework for selecting the best available network for handoff. **[1]** analyzed the impact of utilizing the fuzzy logic system for handoff decision making considering the Global System for Mobile communication (GSM) network. It was shown through simulations that the need to handoff varies depending on the input(s) to the Fuzzy Inference System (FIS). **[5]** introduced the concept of overlap region between adjacent cells and developed an analytical model for soft handoff in WCDMA system. The author also discussed the balking and reneging behaviours of calls and found that the blocking probabilities were decreased as number of channels in a cell or service rate increases. **[6]** developed a method for reducing the number of handoffs in WCDMA system using umbrella Cell technique. The results of the work showed an improvement of the handoff process by large reduction of the number of handoffs, and decreasing the probability of blocked handoffs in the case of umbrella cell technique compared to the other technique. **[7]** developed the design and implementation of a generalized framework for the design of Fuzzy Logic based handoff controller.

2.1 Soft Handoff Algorithm of the WCDMA System

Soft handoff parameters are defined as follows; **[8].**

- ❖ Active set: The set of Base Stations (BSs) that simultaneously connect with a Mobile Station (MS). The BSs in the active set form a soft handoff connection to the MS.
- ❖ Monitored set: The list of BSs that the MS continuously measures the downlink common pilot channel, but whose pilot strengths are not strong enough to be added to the active set.
- ❖ Reporting range: A pre-determined threshold for determining the addition and removal of a radio link.
- ❖ Hysteresis parameter: A pre-determined threshold for determining the addition, removal, and replacement of a radio link.
- ❖ Δ T: The time delay for triggering soft handoff executions.
- ❖ Event 1A (Radio Link Addition): Network establishes a new connection and adds the BS to active set.
- ❖ Event 1B (Radio Link Removal): Network terminates the connection and removes the BS from active set.
- ❖ Event 1C (Radio Link Replacement): Network replaces a BS with another in the active set when active set is full.

- ❖ First, the MS connects with cell 1 only. Cell 2 is added to the active set when M2 higher than M1 plus some handoff parameters for a period of ΔT. This decision can be expressed as;

$$10\ log\ M\ moni\ >\ 10\ log\ M\ act\ best - R1a\ +\ H1a \quad (1)$$

Where M_{moni} is the pilot strength of the new cell in the monitored set, $M_{act\ best}$ is the pilot strength of the best candidate BS in the active set, R_{1a}, and H_{1a} are respectively the reporting range and the hysteresis parameter for Event 1A, M1 and M2 are the pilot strength of cell 1 and cell 2 respectively.

- ❖ The active set is full after adding cell 2. Cell 1 is replaced by cell 3 when M3 is higher than M1 plus a handoff parameter for a period of ΔT. This decision can be expressed as;

$$10\ log\ M\ moni > 10\ log\ Mact\ worst\ +\ H1c \quad (2)$$

Where M_{moni} is the pilot strength of the best candidate cell in the monitored set, $M_{act\ worst}$ is the weakest pilot strength in the active set, M3 is the pilot strength of cell 3, and H_{1c} is a hysteresis parameter for Event 1C.

- ❖ Cell 3 is removed from active set when M3 is lower or weaker than M2 plus some handoff parameters for a period of ΔT. This decision can be expressed as;

$$10\ log\ M\ act\ con < 10\ log\ M\ best\_act - R\ 1b - H1b \quad (3)$$

Where M_{con_act} is the pilot strength of the connected BS in the active set, R_{1b} and H_{1b} are respectively reporting range and hysteresis parameter for Event 1B.

The RSS from the nearest BS may be weaker than that from distant BSs due to deep fading. This is because the variation of signal strength caused by shadow fading is a random process. Therefore, handoff decision mechanisms based on measurements of signal strength induce the ping-pong effect.

3.0 Methodology

3.1 Intelligent Soft Handoff Model/Algorithm

In this paper, an intelligent algorithm has been designed which will provide handoff decision only when it is necessary by considering the distance and direction of MS relative to the target base station. To avoid ping-pong effect, the Fuzzy Logic Inference System (FIS) adds a hysteresis margin due to the distance and the direction of the MS relative to the target BS. The decision of Event 1A is modified as;

$$10\,log\,Mmoni > 10\,log\,Mact\,best - R1a + H1a + D1a + T1a \qquad (4)$$

If the distance between the MS and the BS in monitored set is longer than that between the MS and the main serving BS in active set, the developed algorithm increases a distance hysteresis, denoted as D_{1a}, to increase the difficulty of radio link addition, causing the reduction of handoff probability in Event 1A. Meanwhile, if the MS moves toward the BS in monitored set, a direction hysteresis, denoted as M_{1a}, is decreased to facilitate the radio link addition in Event 1A. On the contrary, developed algorithm increases T_{1a} to decrease the handoff probability in Event 1A if the MS moves away from the BS in monitored set. Therefore, the handoff number can be decreased.

When the active set is full, soft handoff algorithm replaces a weaker radio link with a stronger one. Again, the proposed algorithm adjusts the hysteresis parameters according to MS mobility. The decision of Event 1C is modified as;

$$10\,log\,Mmoni > 10\,log\,Mact\,worst + H1c + D1c + T1c \qquad (5)$$

If the distance between the MS and the BS in monitored set is longer than that between the MS and the BS with the worst link quality in active set, the developed algorithm increases the distance hysteresis, D_{1c}, to increase the difficulty of radio link replacement, causing the reduction of handoff probability in Event 1C. Meanwhile, similar to modified Event 1A, the direction hysteresis, denoted as T_{1c}, is decreased to facilitate the radio link replacement in Event 1C if the MS moves toward the BS with the worst link quality in active set. The proposed method uses more stringent criteria for handoff decisions of Event 1A and 1C and therefore, reduces unnecessary handoffs in the system. The functional block for the FIS used in the developed intelligent soft handoff algorithm is shown in figure1

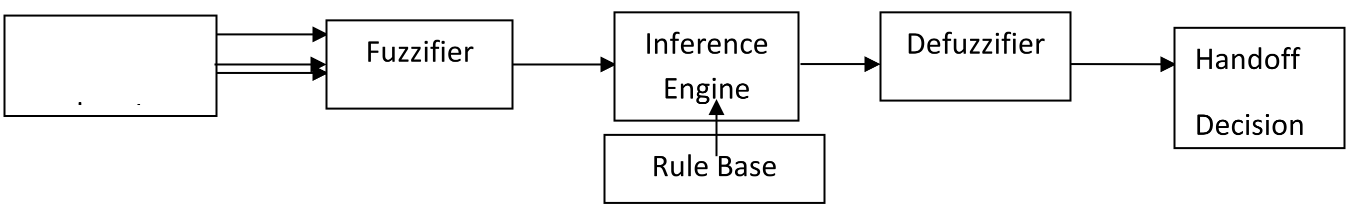

Figure 1**:** Functional Block for the FIS

3.2 The Newly Developed Intelligent Soft Handoff Algorithm

A Fuzzy Inference System (FIS) was developed to provide an intelligent soft handoff decision using the three metrics as input.

The metrics are:

1) Signal Strength (in dBm)

2) Distance from the target Base station (in Meters)

3) Direction from the resultant displacement (in Meters)

Membership function was defined to develop the FIS. A total of 4 linguistic variables were used including Handoff as output. The output variable is the handoff decision made based on the combination of the defined rules. Triangular and trapezoidal membership functions of assigned fuzzy sets were considered. Trapizoidal membership function was considered for edges and the centre part was described using triangular membership function. The non-singelton fuzzifier and the Centre of Area (CoA) de-fuzzification method were used for Mamdani model.

The membership functions of the linguistic variables are given as:

1) Received Signal Strength: (RSS) = {Low, Medium, High}

2) Distance from Base station: = {Near, Far, Very Far}

4) Direction: = {Towards, Medium, Away}

5) Handoff: = {No, Medium, Yes} Measurement Report (MR) of Mobile Station (MS). Distance can be calculated from signal strength or timing advance provided by MR in MS. The direction of MS can be determined by subtracting the current measured distance from the previously measured distance (resultant displacement). The positive or negative sign will indicate the direction of the MS with respect to the target BS; the negative sign indicates that the MS is

approaching and the positive sign indicates that the MS is going away from the BS.

The membership functions of the fuzzy system were designed based on heuristic experience. The parameters are decided as per other research conducted in these area, [3] had heuristic experience, like, signal strength, between -75 dBm and -55 dBm is acceptable as normal (medium) signal strength in telecom industry as used in other literature, therefore it is considered as normal signal strength. For distance, half a kilometre distance is considered far and above a kilometre distance is considered as very far.

After inputting the parameters to the fuzzy interface, it takes some decision on the basis of rules that are predefined. The membership functions of the input to the fuzzy system are shown in figures 2, 3, and 4. Figure 5 is the membership function of the output parameter which is the soft handoff decision. The range lies from 0 to 1.

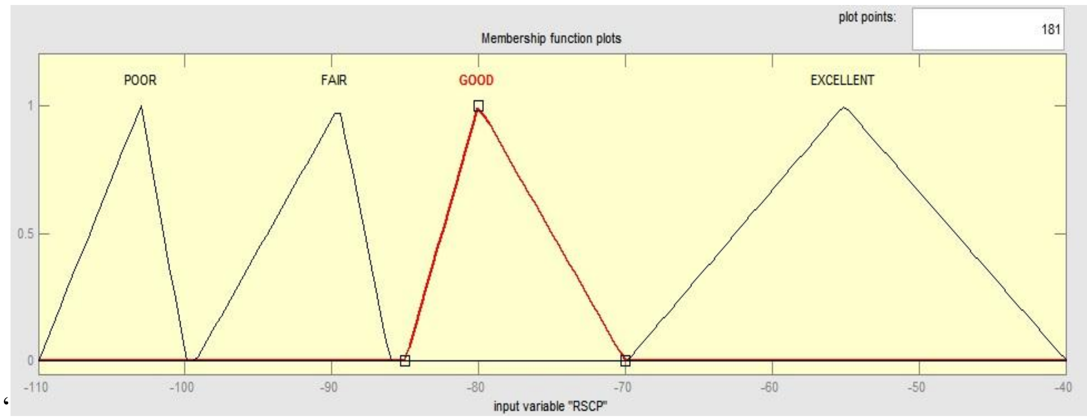

Figure 2: Membership function of RSCP

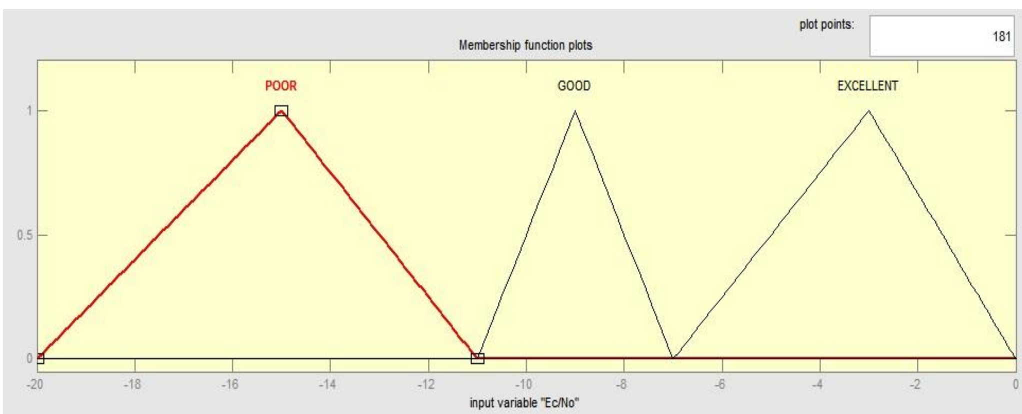

Figure 3: Membership function of Direction

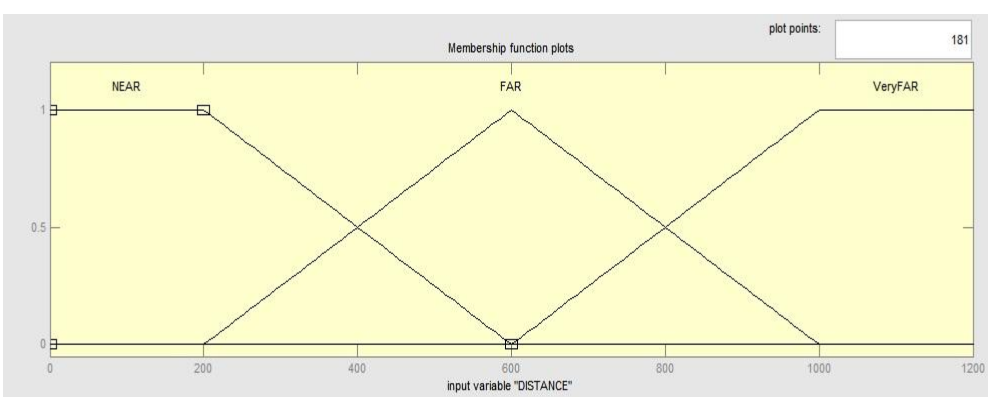

Figure 4: Membership function of Distance

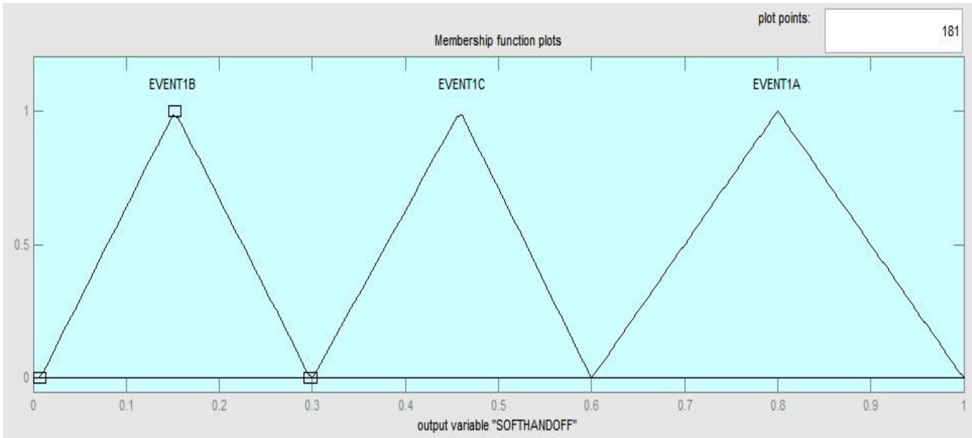

Figure 5: Membership function of Soft handoff decision

The FIS was created with these three inputs and one output variable and there are total of 27 rules (Table 1) based on which the FIS will provide decision

Table 1: Rule Bases for the Fuzzy Logic Control (FLC)

Distance	**Direction**	**RSSI**	**Handoff**
Near	Towards	Low	YES
Near	Towards	Medium	YES
Near	Towards	High	MEDIUM
Near	Medium	Low	YES
Near	Medium	Medium	MEDIUM
Near	Medium	High	NO
Near	Away	Low	MEDIUM
Near	Away	Medium	NO
Near	Away	High	NO
Far	Towards	Low	MEDIUM
Far	Towards	Medium	NO
Far	Towards	High	NO
Far	Medium	Low	NO
Far	Medium	Medium	NO
Far	Medium	High	NO
Far	Away	Low	NO
Far	Away	Medium	NO
Far	Away	High	NO
Very Far	Towards	Low	NO
Very Far	Towards	Medium	NO
Very Far	Towards	High	NO
Very Far	Medium	Low	Medium
Very Far	Medium	Medium	NO
Very Far	Medium	High	NO
Very Far	Away	Low	NO
Very Far	Away	Medium	NO
Very Far	Away	High	NO

The rules are interpreted as follows;

IF the MS is very close or moderately close to the monitored BS and move towards it, THEN the hysteresis for distance and direction are decreased simultaneously and a soft handoff decision is taken accordingly. This ensures that only the best candidate BSs are included in the active set. Also the frequency of inclusion of the BSs into the active set is minimized.

IF the MS is very far from the monitored BS and move towards it, THEN the hysteresis margin for distance is increased while that of the direction is decreased, such that an appropriate soft hand event is favoured.

ELSE the both Hysteresis margins are increased to discourage addition of non-potential BSs in the active set. This reduces the frequency of BSs inclusion in the active set, thereby minimizing the soft handoff overhead as well as the switching load of the system.

The proposed methodology is shown in the flowchart of figure 6

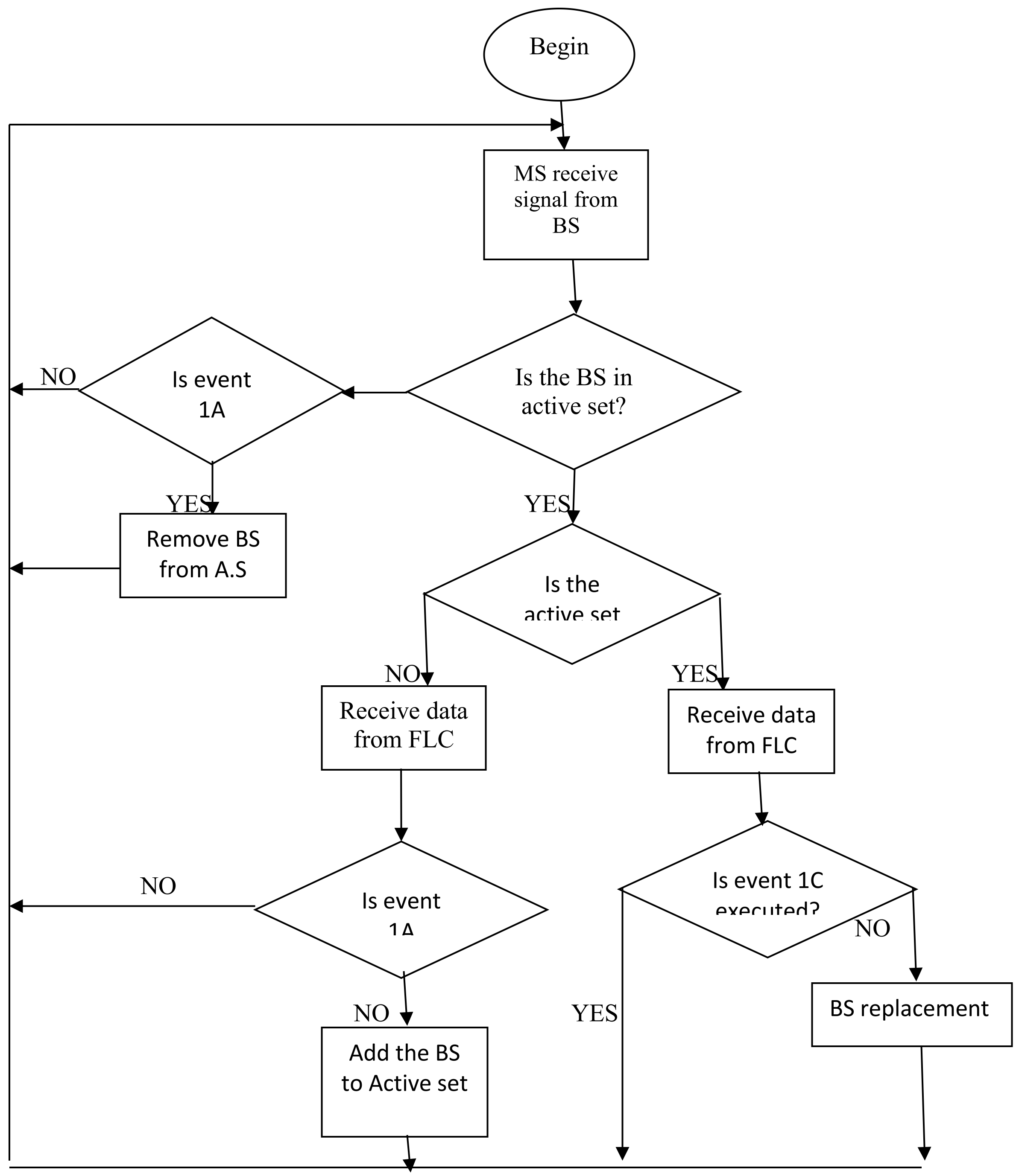

Figure 6: Flow chart of the intelligent soft handoff algorithm

4.0 Results and Discussion

This section represents the graphs of results which are obtained after implementing the intelligent soft handoff algorithm for handoff decision making. The soft handoff criteria should be planned carefully so that there is a compromise between Soft Handoff gain and additional capacity consumption. Inefficient handoff decisions can lead to a ping pong effect and increased number of soft handoff leading to increased use of scarce radio resource. This is because when other important factors such as distance, and MS direction of motion is not considered, the decisions made would lead to increased resource usage when it could have been minimized.

Figure 7 presents the FIS block for the newly developed system and it considers distance, RSSI and direction of the MS to perform any of events 1A, 1B or 1C.

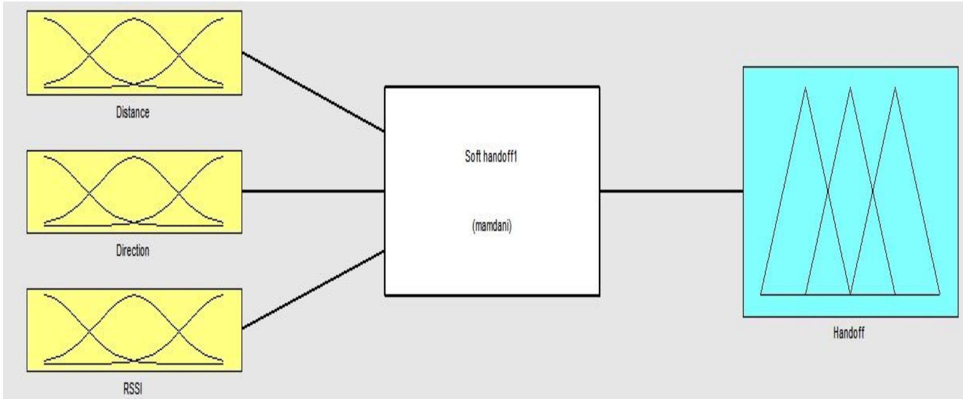

Figure 7: Image of the Fuzzy Logic Simulation Environment

Figure 7 shows that the network takes three inputs and on the basis of 27 rules after the implication of Mamdani fuzzy interface, it generates the single output regarding the soft handoff decision. The relationship of the soft handoff decision with each of the parameters was considered first. The impact of distance on the handoff decision is shown in figures 8, 9 and 10. This plot depicts the various events that are triggered off as the mobile moves around the base stations.

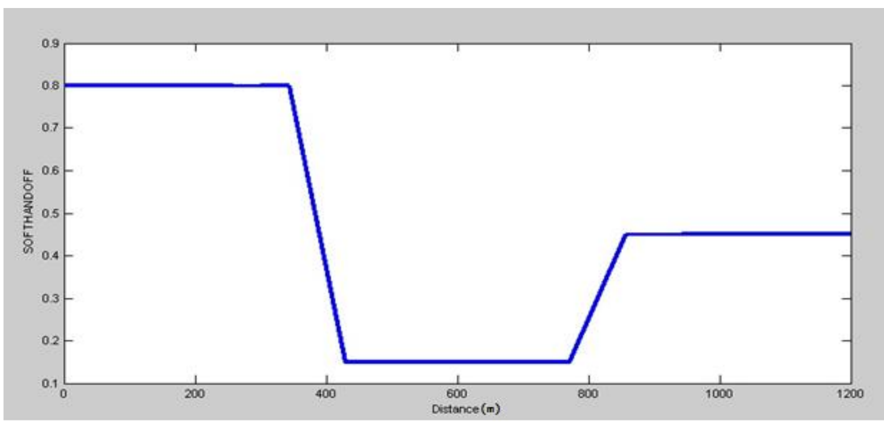

Figure 8: The impact of distance on the handoff decision

Considering the plot shown in figure 8, as the MS moves away from the base station, either of Events 1A, 1B or 1C are triggered depending on the MS proximity to the active set or monitored set. The reference distance in this case is from the first base station before soft handoff was initiated.

Within the distance range of 0 to 200m, the MS is still very much within the vicinity of the first base station at which point event 1A is triggered with a handoff value of 0.8.

The impact of RSSI on the handoff decision is shown in figure 9. This plot depicts the various events that are triggered off as the signal strength fluctuates as the mobile moves around the base station.

From the plot in figure 9, as the signal strength fades due to attenuation or interferences in the propagation environment, the handoff decision tilts from event 1A towards event 1B. This is shown as a sharp dip in the curve as the signal strength fall within the median range for -55dBm to about -70dBm. If the signal strength keeps falling the connection to the first mobile is terminated and event 1C is triggered.

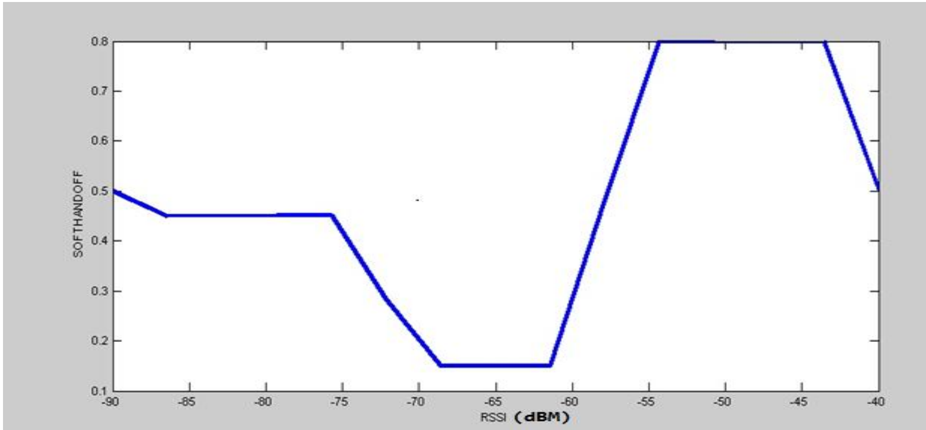

Figure 9: The impact of RSSI on the handoff decision

The impact of direction on the handoff decision is shown in figure 10. This plot depicts the various events that are triggered off as the mobile moves around the base stations.

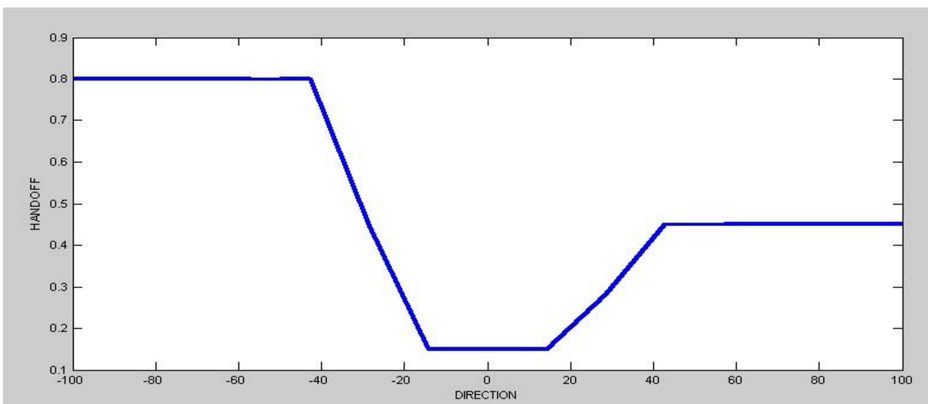

Figure 10: The impact of Direction on the handoff decision

Considering the plot shown in figure 10, as the MS moves towards the base station, either of Events 1A, 1B or 1C is triggered depending on the MS proximity to the active set or monitored set. The direction metric ranges from -100 to 100. The negative sign depicts that the mobile is coming towards the reference base station, while as the MS moves away from the reference BS, the metric starts increasing until it gets to the positive value depicting that the MS is in a direction away from the reference mobile. The reference BS in this case is the first base station before soft handoff was initiated.

Within the direction metric of -100 to -20, the MS is taken to be moving towards the reference base station at which point event 1A is triggered with a handoff value of 0.8. Between the direction metric of 40 to 100, the MS is considered to be moving away from the reference base station at which point, event 1C is triggered off with a handoff value of 0.4. It is important to note that this parameter works efficiently with the distance metric to help the algorithm in making a better decision.

Figure 11 depicts the rule base indication when the MS has a direction metric of -30 (i.e Moving towards the BS) from the first base station. At this point event 1A is triggered with a handoff value of 0.432.

To show the effectiveness of this algorithm, the decision results are compared with that of the conventional system. The rule viewer of the system is shown in figure 11.

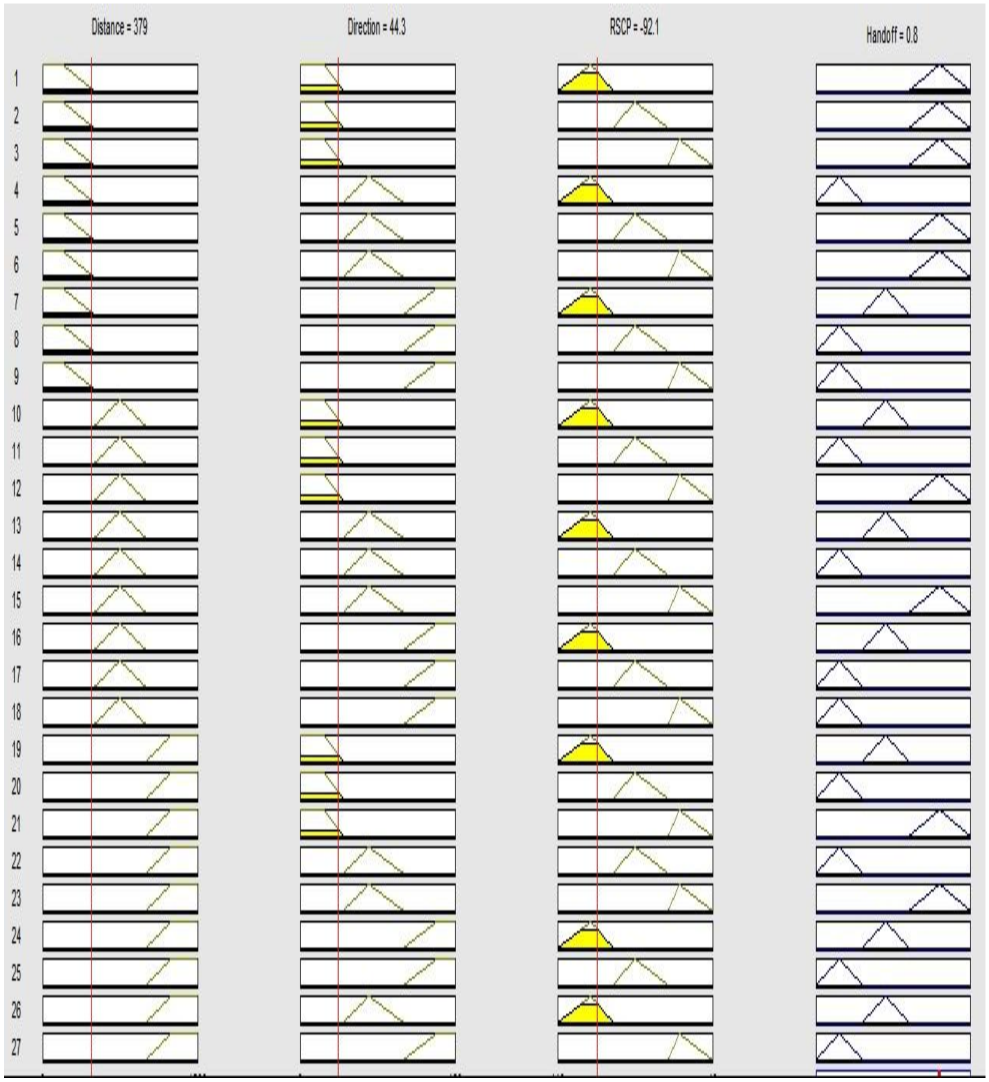

Figure 11: Rule viewer result for the intelligent soft handoff algorithm for a distance of 325m with RSCP of -92.1dBm from cell 1

To indicate the effectiveness of the algorithm, a scenario is considered in figure 12 where the MS is a distance of 325m with RSCP of -92.1dBm (which is considered poor) from cell 1. The handoff decision does not change and thus the user maintains communication with minimal resource usage.

If the conventional system where employed, at the instance where the RSCP drops, a handoff event is triggered even though they might be chances that communication could still be sustained by the cells in the active depending on the distance and direction of motion of the MS.

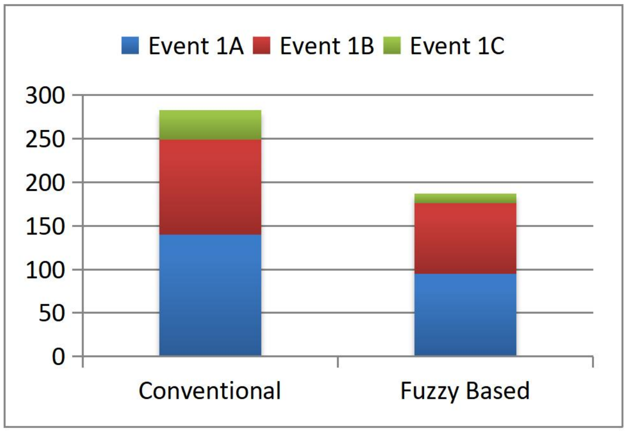

Figure 12: Comparison of Handoffs of Newly Developed Algorithm and the Conventional Algorithm

From the result obtained, it is seen that the fuzzy based algorithm greatly reduces the number of handoff. The total number of handoff events as well as the percentage improvements is given in Table 2:

Table 2: Comparison of the Number of Soft Handoff Events Triggered in both algorithms

Soft handoff Event	**Conventional Method Count**	**Fuzzy Logic based count**	**Improvement (%)**
Event 1a (Radio Link Addition)	140	95	32.1
Event 1b (Radio Link Removal)	I09	81	25.7
Event 1c (Radio Link Replace ment)	34	11	67.6
Total	283	187	33.9

The results show that the fuzzy logic based algorithm reduces the total number of handoff event triggered by 33.9%.

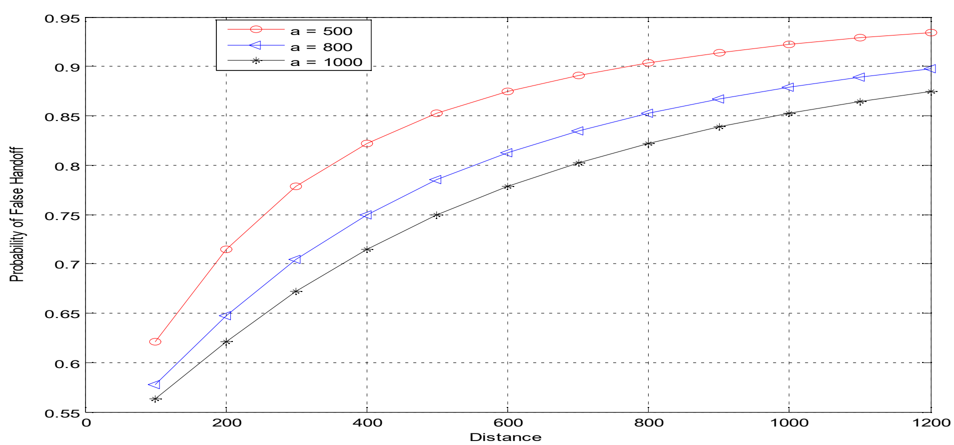

Figure 13: Probability of false handoff initiation for different cell radius

Figure 12 depicts the comparison of handoffs of newly developed algorithm and the conventional algorithm. From the comparison performed, it has been confirmed that the newly developed fuzzy logic soft handoff algorithm outperforms the traditional soft handoff. In traditional technique, the number of soft handoff events totaled 283 whereas the developed fuzzy based algorithm achieved a total soft handoff number of 187. Therefore, figure 13 shows the probability of false handoff with respect to distance. The distance margin incorporated in the developed algorithm helps to check for false handoff initiation as the maximum trigger range is within 400m for each variable of the membership function. This limits the false handoff probability to about 0.71 for a cell radius of 1000m. Correspondingly, if the distance margin is not considered as in the conventional case, the false handoff initiation probability gets up to 0.87. Thus, the fuzzy logic based model developed in this work achieves up to 18.4% reduction in the cost associated with false handoff initiation. The addition of distance and direction parameters initiates the handoff procedures in such a way that there is enough time for the successful execution of the handoff. This avoids too early or too late initiation of the handoff process. The former limits the value of handoff failure probability. The later ensures that handoff is carried out smoothly. Thus, the algorithm optimizes the false handoff initiation probability and handoff failure probability.

5.0 Conclusions

In this work, an intelligent mobility-based handoff decision algorithm has been presented. This method involved distance, direction, and RSS, all of which affect the process of communication. These parameters are considered as input variables for fuzzy inference system, based on the handoff decision parameters, reasoning rules were designed while considering their logical relationships. The fuzzy inference system was considered to be a suitable system for reason based on non-linear data i.e. terminal as well as network information. The developed algorithm intelligently adds a hysteresis parameter associated with distance between the mobile and surrounding base stations and a hysteresis parameter associated with the mobile heading direction in Event 1A and 1C. The performance was verified by applying the developed algorithm to a WCDMA system in Onitsha urban city. The result shows that the developed intelligent algorithm improves the handoff number about 33.9% over the conventional one and reduces the probability of false handoff to about 18.4%. The developed intelligent algorithm was able to ensure;

• Significant reduction in soft handoff number and false handoff probabilities

• That there is no added computation complexity and extra hardware burden, but some software updating in RNC is enough, which may affect the computation complexity.

References

[1] Nyambati Emily Teresa and Oduol Vitalice K, “Analysis of the Impact of Fuzzy Logic Algorithm on Handover Decision in a Cellular Network”, International Journal for Innovation Education and Research (www.ijier.net) Vol: 5 No-05, 2017, Pp 46 – 49.

[2] Bhavtosh Awasthi and Beena Bundela, Queueing “Model For Soft Handoff Analysis In WCDMA Wireless Cellular Network”, International Journal of Advanced Research in Computer Science, 9 (1), 2018, Pp 91-95

[3] Kaur Rupinder & Harnek Singh, “An Efficient Approach for Handover Decision Making In Wireless Networks”, International Research Journal of Engineering and Technology (IRJET), Volume 5, Pp. 454-458, 2018

[4] Ekpenyong Moses, Asuquo Daniel, Robinson1 Samuel, Umoren Imeh, and Isong Etebong, “Soft Handoff Evaluation and Efficient Access Network Selection in Next Generation Cellular Systems”, Advances in Science, Technology and Engineering Systems (ASTES) Journal Vol. 2, No. 3, Pp 1616-1625, 2017.

[5] Awasthi, “Handoff Analysis in WCDMA Based Wireless Cellular Network using Hard Handoff Model”, Journal of Computer and Mathematical Sciences, Vol.8, no. 12, pp. 739-749, 2017.

[6] Lujain S. Abdulla, (2016) “Improving Handover Process In WCDMA System Using Umbrella Cell Technique”, Quarterly Adjudicated Journal for Natural and Engineering Research and Studies, Vol. 3, No. 5 and 6, Pp 35-47.

[7] Sachdeva Manish and Kumar Pankaj, “A Survey of Handoff Strategy and Fuzzy Logic with Desired Quality of Service”, International Journal of Innovative Science, Engineering & Technology (IJISET), Vol. 2 Issue 10, 2015, Pp. 316 – 319.

[8] Lamia Bakri Abd elhaleem Derar and Amin Babiker Abd elnabi Mustafa, “Improvement Performance of Soft Hand Over on UMTS Network”, Journal of Scientific and Engineering Research, 2014, Pp. 1-11.