Identification of Suitable Parameters for Predicting Handoff in Real Time Mobile Network Technologies

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***Abstract*— Future wireless networks will consist of multiple heterogeneous access technologies such as Universal Mobile Telecommunications Service (UMTS), Global System for Mobile Communication (GSM), Long Term Evolution (LTE) and Worldwide Interoperability for Microwave Access (Wi-Max). The main challenge in these networks is to provide users with a wide range of services across different radio access technologies through a single mobile terminal. The mobile users are demanding access to the wireless networks at anytime and anywhere. To ensure the service continuity and to maintain the promising Quality of Service (QoS), the decision regarding handoff is to be taken appropriately. The most common criteria for handoff is the Received Signal Strength (RSS). Now a day's integration of different wireless access technologies has become more important so that the user is made available to get access without any discontinuity. In such integrated environment to provide seamless mobility, Vertical Handoff (VHO) is one of the major issues which need to be addressed for providing better QoS. The vertical HO scenario introduces issues related to QoS which affects the connections as well as the applications. This paper identifies different parameters which are responsible for a fruitful handoff process by comparing handoffs in different mobile networks like UMTS, GSM, WiMAX, and LTE. The paper also discusses about the path traversed by the HO decision process and find out the parameters which are useful to make accurate HO decision.**

***Keywords*—Vertical Handoff (VHO), Received Signal Strength (RSS), Quality of Service (QoS), WiMAX, UMTS, GSM, LTE, Signal Interference to Noise ratio (SINR).**

I. INTRODUCTION

Future wireless networks aim is to provide universal ubiquitous coverage across different radio technologies, in which a multi-model mobile terminal (MT) will be able to connect to wireless access networks simultaneously. Users expect service providers to offer permanent connections while roaming between networks. A large variety of applications utilizing these networks will demand features such as real time, high availability across different access technologies in a seamless way. However, the support to mobility raises new issues related not only to hand off management such as low disruption time, but also the Quality of Service (QoS).

The trend of future wireless network is to provide accessibility for connecting to any network anywhere and anytime. In such system, user will be roaming among different wireless access technologies which could be done via Vertical Handoff.

Handoffs can be divided into two types: Horizontal and Vertical. In horizontal handoff which occurs between similar accesses technologies, the handoff decision is mainly based on Received Signal Strength (RSS) in the border region of two cells. However, in vertical handoff, the situation is more complex, compared to the horizontal handoff. For example, the signal strength is sometimes not sufficient to trigger the vertical handoff as heterogeneous networks have different characteristics and their performance cannot be simply compared using the signal strength of two cells. Other new metrics such as service type, system performance, network conditions, mobile node conditions, user preferences etc. must also be considered. Another challenge is that the vertical handoff may not only take place at the cell edge but it could also occur at any time depending on the network condition and user preference such as in a situation of network congestion.

The vertical handoff process can be broken into three phases: system discovery, handoff decision, and handoff execution, as shown in fig 1. During the system discovery phase, mobile stations collect available services, supported QoS, and link/network status in each network. The networks may advertise the supported data rates for different services. During the handoff decision phase, the mobile device determines the best network to connect to. The decision is based on various parameters such as available bandwidth, delay, jitter, access cost, transmission power, current battery lifetime, and the user's preferences. The handoff decision may be forced upon a mobile station when the connection to the current network is about to be broken. This is similar to a handoff in a horizontal handoff. The handoff decision may be continuous as a mobile station continually monitors parameters in multiple networks. Once a decision is made to perform the handoff, connections need to be re-routed from the existing network to the new network in a seamless manner. This phase also includes the authentication and authorization, and the transfer of user's context information.

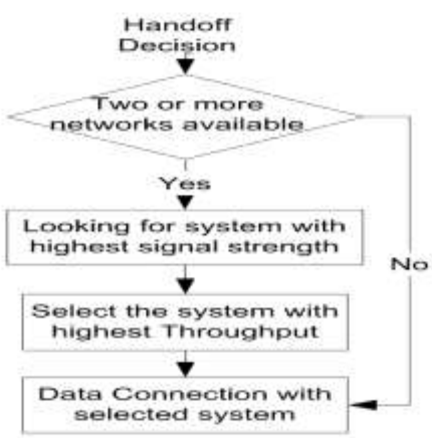

Fig.1 Flow chart showing handoff management process

II. LITERATURE REVIEW

E.Rajinikanth et. al [1] have proposed an identification scheme which identifies different parameters like RSS, Bandwidth, speed, cost, direction, SINR etc. which are responsible for a fruitful handoff process. The algorithms for the path traversed by the handoff decision process had also been studied in this paper.

The authors in [2] have discussed about the HO decision made by the network mobility HO with media independent handover (MIH) IEEE 802.21 standard considering the link layer information like link quality, speed security etc. Based on the information provided by MIH, the decision algorithm selects the best interface to perform HO for reducing the signaling and number of HO. This algorithm can guarantee QoS and decrease the blocking probability.

Sui Bo et.al [3] have proposed a Mobility based multi-attribute vertical HO (MMVHO) scheme made by access point based on the node mobility characteristics which has a centralized HO control. There is also a pre- HO algorithm which picks the correct access point by analyzing the movement characteristics. The HO trigger depends on the signal coverage of the access point and also implements centralized HO control which leads to HO failure probability to be 1.

The mobile node speed and the application bit rates have been taken as decision making inputs to achieve seamless mobility by combining algorithms with MIH IEEE 802.21 standard in [4]. It is clear that for node speed greater than 60km/hr, throughput degrades because of less time for preparation and decision making. The end-to-end delay are affected by the bit rates rather than node speeds, acceptable end-to-end delays values are 54ms for most applications but delay is increased as the bit rate exceeds available bandwidth. Link Going Down (LGD) probability depends on mobile node speed, handover initiation and decision in particular time interval which results in service continuity. The acceptable latency for low to high quality voice is from 150 to 200ms and for non-interactive video, the acceptable latency is 280 ms.

A Multicriteria VHO process model with pre selection scheme using MT speed, RSS, location of mobile terminal/base station/access point (MT/BS/AP) and QoS of the serving network based on Fuzzy logic have been proposed in [5]. The pre-selection scheme checks the MT distance and checks its velocity with the threshold for performing HO to minimize unnecessary HO. The process model can be combined with HO network selection module to obtain seamless and successful HO.

Sunisa Kunarak et.al [6] have proposed a Multiple HO decision criteria based on the predictive RSS (PRSS), dwell time and merit function for optimal network selection. The dwell timer is used to check continuity of PRSS, where it is possible to decide the early HO, which also lowers the dropping probability, packet delay and increases the throughput when moving in overlay networks.

An algorithm have been proposed in [7] which tries to reduce the handover switching delay and decision uncertainties by using the grey prediction algorithm (GPA) based Quantitative Decision Algorithm (GPQDA) which is based on the effect of hysteresis. The algorithm is based on RSS, bandwidth and service cost which is able to predict handover at soaring mobility in fading environments. The above paper has few uncertainties in decision making using fuzzy systems which has to be focused.

Miyim et. al [8] proposed a prioritized network based VHO in which the main factors to make control of VHO process are considered. Those factors are location, speed, time with respect to signal strength threshold. Through this algorithm, it is possible to predict handover before it is estimated. The number of handover is reduced as the RSS of the VHO gets stronger and the MS resides for longer time in the network and also there is no break in the service.

A multi-criteria vertical handoff (MVHO) decision making is considered in [9] which consists received signal strength indicator (RSSI), moving speed, traffic by the MS and also the network occupancy as the deciding parameters. The author had achieved 46.21% reduction in number of HO and the mean initial number of HO had been reduced to 73 from the conventional method of 157. The paper considers network occupancy as the main factor for decision making in HO.

Mario Pink et al [10] have proposed an Adaptive fuzzy based handover decision which fine-tunes itself with respect to the device and network capabilities. In this algorithm Markov decision processes with Q-learning and genetic algorithms are implemented for the improvement of decision quality. The accuracy of handover decision, QoS and resource consumption are evaluated and found that maximum throughput have been obtained with greater accuracy in decision making.

Thus there is a need of comparison of various vertical handoff algorithms for existing technologies which will be based on various handoff parameters that are discussed in Section III. The proposed paper uses software tool and methodology that is mentioned in Sections IV & V respectively. Finally the conclusions are made in Section VI.

III. HANDOFF PARAMETERS

A horizontal handoff is triggered typically by a link quality. A vertical handoff may consider more factors into account, such as bandwidth, battery life, connection cost, etc which are discussed in detail as below and is mentioned in fig 2:

1) *Service type*: Different types of services require various combinations of reliability, latency, and data rate. For example, when a mobile has a video download and when it switches to another wireless network, capability of supporting real-time high-bandwidth traffic may be a predominant factor in deciding which wireless network to choose for the handoff.

2) *Network conditions*: Network-related parameters such as traffic, available bandwidth, network latency, and congestion (packet loss) may need to be considered for effective network usage. Use of network information in the choice to handoff can also be useful for load balancing across different networks, possibly relieving congestion in certain systems. Network conditions used are received signal strength indicator (RSSI), receiver level (RxRec Level), receiver quality (Rx Qual), Handover Margin, pilot quality (Ec/Io), Ec/Io Margin, carrier to interference ratio (C/I), bit error rate (BER).

3) *System performance*: To guarantee the system performance, a variety of parameters can be employed in the handoff decision, such as the channel propagation characteristics, signal strength, path loss, channel interference, signal-to-noise ratio (SNR), and the bit error rate (BER).

4) *Mobile Node conditions*: Mobile condition includes dynamic factors such as velocity, moving pattern, moving histories, battery power, and location information.

5) *User preferences*: User preference can be added to cater to special requests for users that favor one type of system over another.

6) *Available bandwidth:* It is a measurement of available or consumed data communication resources expressed in bits per second. It is a good indicator of traffic conditions in the access network and is especially important for delay-sensitive applications

7) *Power consumption:* If a MT's battery is low it becomes a critical issue. In such case it would be preferable to handover to a point of attachment (PoA) which would help extending valuable battery life.

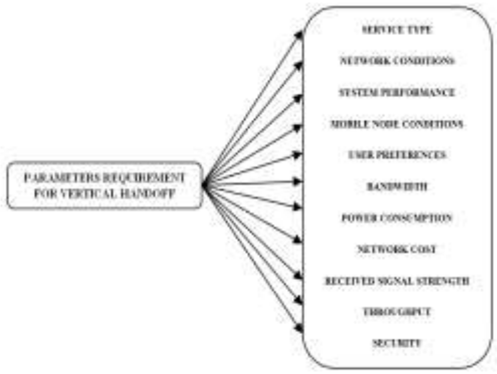

Fig.2 Parameters used for making vertical handoff decisions

8) *Monetary cost:* For different networks, there would be different charging policies, therefore, in some situations the cost of a network service should be taken into consideration in making handover decisions.

9) *Received signal strength (RSS):* Handover decision is a handover initiation phase in homogeneous environment. RSS is the traditional handover decision criteria in almost all existing horizontal handover algorithms. RSS is also an important decision criterion in the vertical handoff decision (VHD) algorithms. Received signal strength (RSS) is the most widely used criterion because it is easy to measure and is directly related to the service quality. There is a close relationship between the RSS readings and the distance from the mobile terminal to its point of attachment. Majority of existing horizontal handover algorithms use RSS as the main decision criterion, and RSS is an important criterion for VHD algorithms as well.

10) *Security:* For some applications, confidentiality or integrity of the transmitted data can be critical. For this reason, a network with higher security level may be chosen over another one which would provide lower level of data security.

11) *Throughput:* It refers to the data rate delivered to the MT on the network. Handover to a network candidate with higher throughput is usually desirable.

IV. PROPOSED SOFTWARE TOOL

The software tool includes ATOLL (version 3.1.1) and TEMS (TEst Mobile System) Investigation and a snapshot of the Atoll software is mentioned in fig 3.

Atoll is a scalable and flexible multi-technology network design and optimisation platform that supports wireless operators throughout the network lifecycle, from initial design to densification and optimisation. It can be used to plan both radio networks and microwave links.

Atoll can automatically determine handover relations between networks of different technologies.

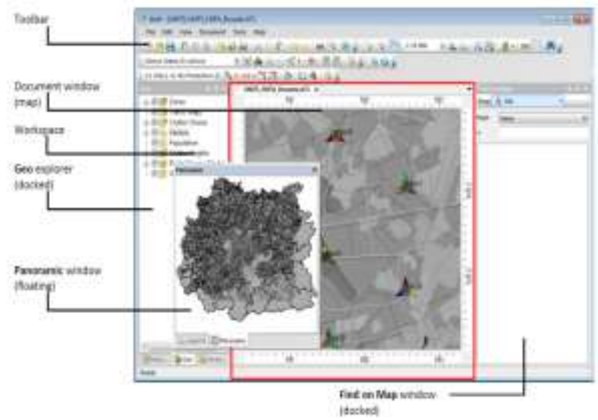

Fig.3 Atoll user interface

TEMS Investigation is the industry standard tool for troubleshooting, verification, optimization and maintenance of wireless networks. TEMS Investigation has been the leading originator of drive-testing features. It employs smart and exclusive functionality that solves specific problems, promotes cost-efficient work processes, minimizes human errors and improves productivity, allowing operators to focus on ensuring network quality, as well as gain insight into the subscriber perspective by performing service testing directly on the end terminal.

The measurement setup used, as mentioned in fig 4 is a drive test equipment which performs tests in a cellular network and collects data on a moving vehicle. The software and hardware used are: Laptop with charger and universal serial bus (USB) hub, global positioning system (GPS) and data cable, Digital Radio Frequency (RF) Scanner, License dongle for TEMS, Cell site database and Link budget, Clutter diagram from Google website, Engineering handsets with 4 (2G/3G) SIMs of different operators mounted simultaneously and cable terminal. In the setup, data collection software is installed in the laptop which uses a mobile phone along with GPS system.

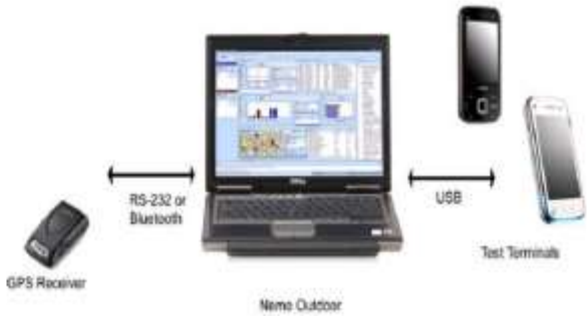

Fig.4 Device arrangement in drive test tool (Tems Investigation)

V. PROPOSED METHODOLOGY

In case of handover between LTE and GSM, inter-technology handover from LTE to GSM may occur when the LTE coverage is not continuous. The network's overall coverage is extended by an LTE-to-GSM handover. Atoll can automatically determine neighbours in the linked document for cells in the main document and vice versa. Inter-technology neighbours are stored in the database.

The Digital Terrain Model (DTM) describes the elevation of the ground over sea level. You can display the DTM in different ways: by single value, discrete values, or by value intervals. The DTM is automatically taken into account by the propagation model during computations.

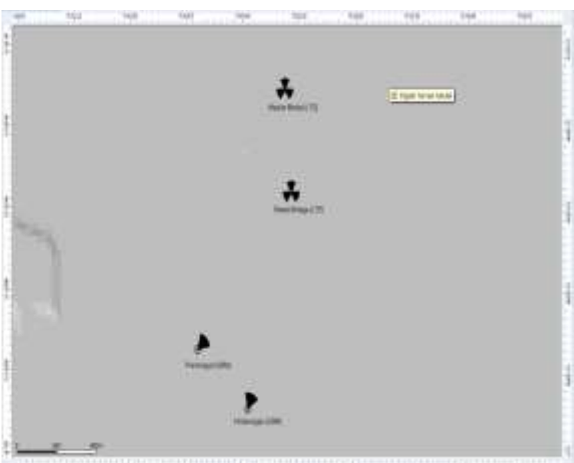

Fig.5 Digital Terrain Model showing LTE and GSM Transmitters

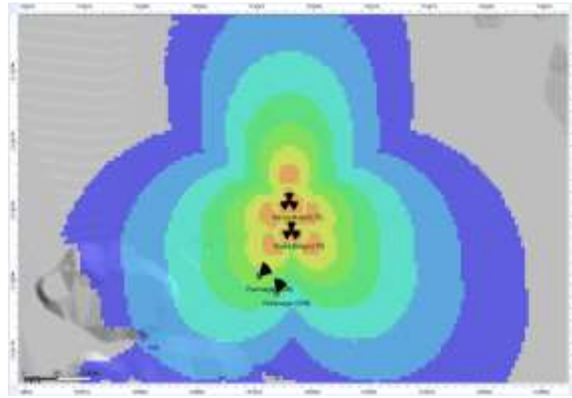

Fig.6 Prediction Model for LTE Transmitters

In the prediction model shown in figure 6, the prediction is done with respect to one of the important criteria, coverage by signal level. In this model red colour represents best signal level which is equal to or more than -70 dBm and hence the signal gradually fades as one goes from red to blue. Appropriate signal level for calls is taken to be up to -90 dBm. Thus, our consideration of signals for proper working would be from the range of red to green colour. As it could be seen that the two GSM transmitters i.e., transmitters at Premnagar and Hridainagar sites will receive signals from the two LTE transmitters in addition to their own signals.

Now mobile terminals at places in the ranges of both LTE and GSM transmitters will have to decide which signal level from which transmitter will be appropriate for the continuation of their respective calls. To take such decisions Arbitrary Strength Unit (ASU) an integer value proportional to the received signal strength is measured by the mobile phone. The estimated received signal strength in a mobile device can be estimated as follows:

$$dBm_e = -113.0 - 40.0\log_{10}(r/R)$$

Generally the path loss exponent could be taken as:

$$dBm_e = -113.0 - 10.0\,\gamma\log_{10}(r/R)$$

where dBm_e is estimated power in mobile device, -113 is minimum received power, average path loss per decade for every mobile is 40, r is distance of mobile device from cell tower, R is mean radius of cell tower and γ is path loss exponent.

In LTE networks, ASU maps to RSRP (reference signal received power). The valid range of ASU is from 0 to 97. For the range 1 to 96, ASU maps to (ASU - 141) $\leq$ dBm < (ASU - 140).

The value of 0 maps to RSRP below -140 dBm and the value of 97 maps to RSRP above -44 dBm.

In this paper, the model used is Okumara-Hata Model because it is preferable in case of urban and suburban areas.

The path loss formula can be given as:

$L = 69.55 + 26.16 \log f - 13.82 \log h_b - a.h_m + [44.92 - 6.55 \log h_b].\log d - L_c$

where L_c is particular correction factor for different terrain type, f is frequency of technology used, h_b is height of base station in meters, h_m is height of mobile antenna in meters, a is correction factor of mobile and d is distance between mobile and tower in kilometers.

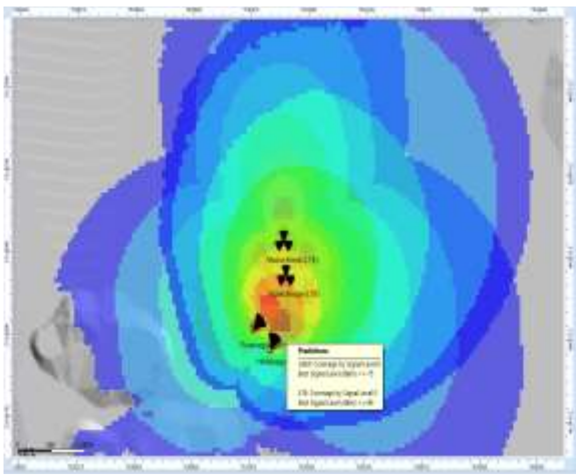

Fig.7 Combined Prediction Model for both LTE and GSM transmitters

Figure 7 shows that at 79.921998241E latitude and 23.150424008N longitude signal level of GSM transmitter is -75 dBm while that for LTE it is -90 dBm. Hence a mobile terminal using LTE coverage should handoff to attain GSM coverage.

If more technologies are working together as it happens now a days it will be required to calculate all the necessary parameters by changing values like frequency, height of transmitters, azimuth angle of transmitters, etc. and then comparison is done between all the technologies available and the best one is opted.

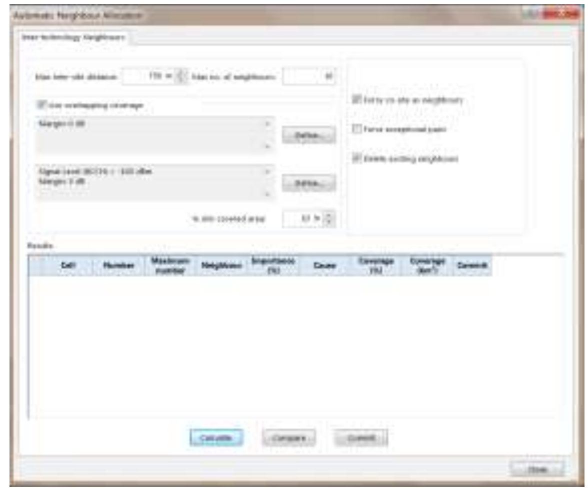

Fig.8 Automatic Neighbour Allocation for Max inter-site distance = 750m

Fig.9 Neighbours Delta Report for Fig.8

According to figure 8 and figure 9 at maximum inter-site distance equal to 750m there does not exist any neighbour with whom handoff could occur in case of poor signal quality.

This happens since the least distance from an LTE site to a GSM site is 759m. Thus, if max inter-site distance is kept less than this distance no inter-site neighbours could be obtained. To calculate and compare neighbour sites it is required to keep max inter-site distance more than 759m.

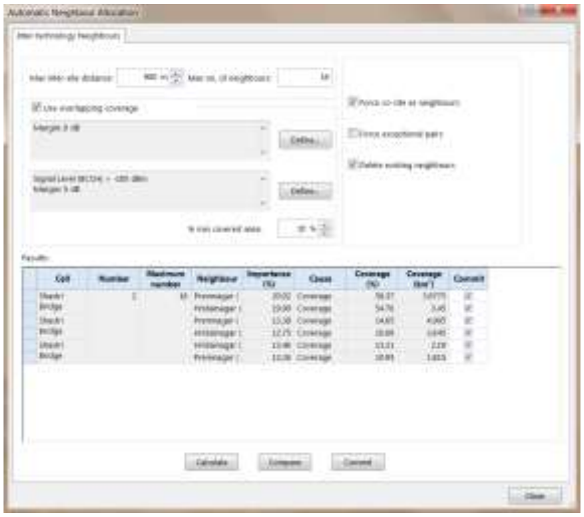

Fig.10 Automatic Neighbour Allocation for Max inter-site distance = 900m

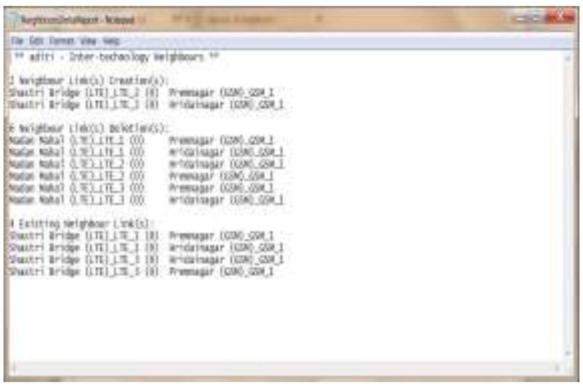

Fig.11 Neighbours Delta Report for Fig.10

As compared to figure 8 and figure 9 there are 2 neighbour links that are created in addition to 4 already existing ones and 6 links are being deleted in figure 10 and figure 11.

As already mentioned earlier Atoll can automatically determine neighbours in the linked document for cells in the main document and vice versa one can change the suitable parameters (like received signal strength indicator, RxRec Level, receiver quality, Handover Margin, pilot quality (Ec/Io), Ec/Io Margin, carrier to interference ratio, bit error rate, signal strength, path loss, channel interference and signal-to-noise ratio (SNR)) as per requirement for proper handoff and this could be done in following manner using Atoll.

To automatically allocate neighbours in the linked document for cells in the main document:

A. Click the main document's map window.
B. Select the Network explorer.
C. Right-click the LTE Transmitters folder. The context menu appears.
D. Select Neighbours > Inter-technology > Automatic Allocation from the context menu. The Automatic Neighbour Allocation dialogue appears.
E. Click the Inter-technology Neighbours tab.

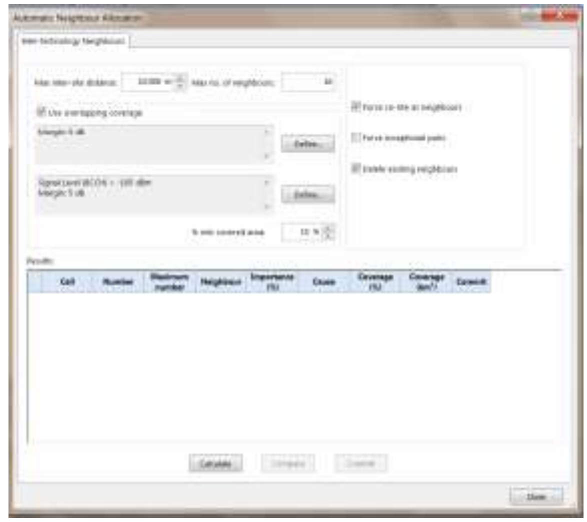

Fig.12 Inter-technology Neighbours tab in Neighbour Allocation dialogue box

F. Define the maximum distance between the reference cell and a possible neighbour in the Max inter-site distance box.
G. Define the maximum number of inter-technology neighbours that can be allocated to a cell in the Max number of neighbours box. This value can be either set here for all the cells, or specified for each cell in the Cells table.
H. Clear the Use overlapping coverage check box in order to base the neighbour allocation on distance criterion and continue with step 9. Otherwise, select the Use overlapping coverage check box if you want to base the neighbour allocation on coverage conditions.

1) Click the Define button to change the coverage conditions for the cells in the main document. The LTE Coverage Conditions dialogue appears.

Fig.13 LTE Coverage Conditions dialogue box

In the LTE Coverage Conditions dialogue, you can change the following parameters:

i. *Resolution:* You can enter the resolution used to calculate the coverage areas of cells for the automatic neighbour allocation.
ii. *Margin:* Enter the margin relative to the reference signal level of the best server. The reference signal level of the neighbour transmitter is either the highest one or within a margin of the highest one.
iii. *Shadowing taken into account:* If desired, select the Shadowing taken into account check box and enter a Cell edge coverage probability.
iv. *Indoor coverage:* If desired, select the Indoor coverage check box. Atoll will then calculate additional losses for indoor coverage.

2) Click OK to save your modifications and close the Coverage Conditions dialogue.
3) Click the Define button to change the coverage conditions for the transmitters/cells in the linked document.

If the linked document is a GSM document, the GSM Coverage Conditions dialogue appears. In the GSM Coverage Conditions dialogue, you can change the following parameters:

i. *Resolution:* You can enter the resolution used to calculate the coverage areas of cells for the automatic neighbour allocation.
ii. *Min. BCCH signal level:* Enter the minimum BCCH signal level which must be provided by the GSM transmitter.
iii. *Margin:* Enter the margin relative to the BCCH signal level of the best server. The BCCH signal level of the neighbour transmitter is either the highest one or within a margin of the highest one.
iv. *Shadowing taken into account:* If desired, select the Shadowing taken into account check box and enter a Cell edge coverage probability.
v. *Indoor coverage:* If desired, select the Indoor coverage check box. Atoll will then calculate additional losses for indoor coverage.

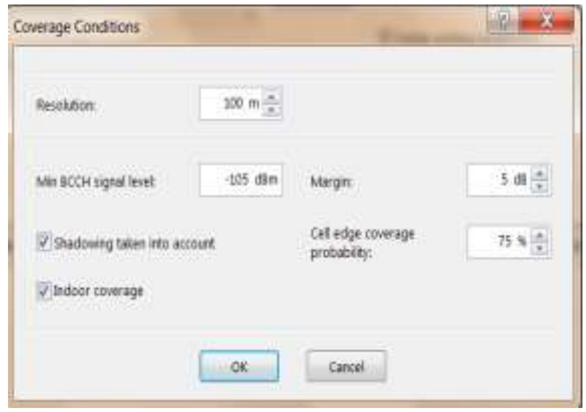

Fig.14 GSM Coverage Conditions dialogue box

If the linked document is a UMTS document, the UMTS Coverage Conditions dialogue appears. In the UMTS Coverage Conditions dialogue, you can change the following parameters:

i. *Resolution:* You can enter the resolution used to calculate the coverage areas of cells for the automatic neighbour allocation.
ii. *Min pilot signal level:* Enter the minimum pilot signal level which must be provided by the reference cell.
iii. *Min Ec/Io:* Enter the minimum Ec/Io which must be provided by the reference cell.
iv. *Ec/Io margin:* Enter the Ec/Io margin relative to the Ec/Io of the best server. The reference cell is either the best server in terms of pilot quality or a cell of the active set.
v. *Max Ec/Io:* Select the Max Ec/Io option and enter the maximum Ec/Io which must not be exceeded by the reference cell.
vi. *DL load contributing to Io:* You can select whether Atoll should use a Global value (% Pmax) of the downlink load for all the cells, or the downlink loads Defined per cell.
vii. *Shadowing taken into account:* If desired, select the Shadowing taken into account check box and enter a Cell edge coverage probability.
viii. *Indoor coverage:* If desired, select the Indoor coverage check box. Atoll will then calculate additional losses for indoor coverage.

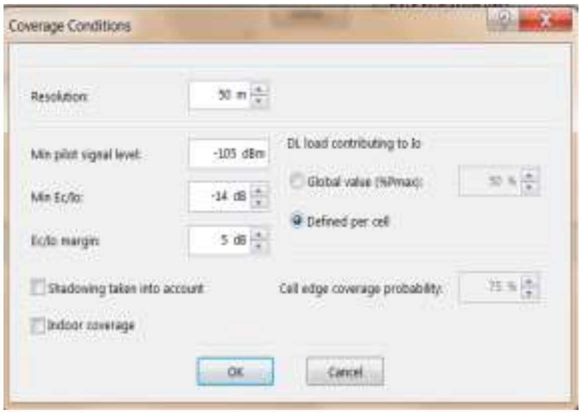

Fig.15 UMTS Coverage Condition dialogue box

4) Click OK to save your modifications and close the Coverage Conditions dialogue.
5) In the % min covered area box, enter the minimum percentage of the cell's coverage area that the neighbour's coverage area should also cover to be considered as a neighbour.

I. Under Calculation options, define the following:

CDMA carriers: If the linked document is a UMTS, CDMA, or TD-SCDMA document, select the carriers on which you want to calculate the allocation. You can choose one or more carriers; Atoll will allocate only the cells using the selected carriers as neighbours.

i. *Force co-site as neighbours:* Selecting the Force co-site as neighbours check box will include the co-site transmitters/cells in the neighbour list of the LTE cell. The check box is automatically selected when the neighbour allocation is based on distance.
ii. *Force exceptional pairs:* Selecting the Force exceptional pairs check box will apply the inter-technology exceptional pair criteria on the neighbours list of the LTE cell.
iii. *Delete existing neighbours:* Selecting the Delete existing neighbours check box will delete all existing neighbours in the neighbours list and perform a clean neighbour allocation. If the Delete existing neighbours check box is not selected, Atoll keeps the existing neighbours in the list.

J. Click the Calculate button to start calculations.
K. Once the calculations finish, Atoll displays the list of neighbours in the Results section. The results include the names of the neighbours, the number of neighbours of each cell, and the reason they are included in the neighbours list.
L. Select the check box in the Commit column of the Results section to choose the inter-technology neighbours you want to assign to cells.

At this point you can compare the automatic allocation results proposed by Atoll with the current neighbour list (existing neighbours) in your document.

To compare the proposed and existing neighbour lists:

i. Click Compare. The list of automatically allocated neighbours, whose Commit check box is selected, is compared with the existing list of neighbours. A report of the comparison is displayed in a text file called NeighboursDeltaReport.txt, which appears at the end of the comparison. This file lists:
ii. The document name and the neighbour allocation type
iii. The number of created neighbour relations (new neighbour relations proposed in the automatic allocation results compared to the existing neighbour relations) and the list of these relations
iv. The number of deleted neighbour relations (neighbour relations not proposed in the automatic allocation results compared to the existing neighbour relations) and the list of these relations
v. The number of existing neighbour relations (existing neighbour relations that are also proposed in the automatic allocation results) and the list of these relations.

M. Click the Commit button. The allocated neighbours are saved in the Inter-technology Neighbours tab of each cell.
N. Click Close.

After calculating for various conditions for every technology being available comparison is done between all the necessary criteria used for handoff as well as analysis of terrain, study of different obstacles whether natural or manmade is done and finally call can be transferred to the base station with appropriate technology.

Hence using the automatic allocation of neighbours by Atoll software we can compare different technologies working together and opt for the best one by changing one or many parameters needed for successful as well as fruitful handoffs. Also we can study the geographic conditions of the area of interest.

VI. CONCLUSION

In multinetwork environment, integration plays a vital role to provide seamless services to the users. In such multinetwork environment the main focus will be on the Vertical Handoff and its decision making parameters. The most widely used input parameters for decision process are RSS, Bandwidth, speed, cost, direction, SINR for achieving seamless mobility. As the evaluation function for handover decisions become more complex, delays increases significantly. For real-time applications, this may not be feasible or appropriate. As such, there is need for ongoing work to develop hybrid methods that can yield optimal results without being overly complex with some form of adaptive or intelligent behavior to handle uncertainty and address the dynamic nature of mobile environments. Also it is required to find out a solution for proper decision making, to increase the performance. Selecting suitable parameters for performing handoff decision is a major concern in multinetwork environment and the performance can be analyzed for better QoS and user satisfaction.

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