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ABSTRACT

This paper proposes a novel call admission control (CAC) algorithm that considers various types of applications with various QoS parameters requested by a user and provides the required QoS to newly admitted users without a degradation of the QoS to already admitted ones. The proposed CAC is evaluated for a heterogeneous radio access technologies (RATs) scenario. The QoS parameters vary depending on the type of applications and the agreement between the service provider and the user. The proposed CAC is based on a fuzzy logic mechanism that comprises two stages; in the first stage the best cell in each RAT is selected by using a fuzzy linguistic controller, and in the second stage the best RAT based on the user preferences is selected using the fuzzy multiple attribute decision making (MADM) method. The results show that the user is able to select the best cell in each RAT using the cell selection algorithm and the cell admittance factor (CAF) values obtained for each cell in a RAT. The best RAT is selected based on the weights assigned by the user to data rate, latency and BER, mobility and the service cost. The RAT that best fits the user needs is selected from the ranks assigned by the RAT selection algorithm to each RAT.

I. INTRODUCTION

II. A flexible architecture for the distribution of optical and the transparent transport of radio signals based on the joint processing of the radio signals from distinct remote antenna units (RAU) and supported by a transparent fibre infrastructure was proposed in by the EU-funded FP7 project FUTON [1]. The architecture enables the provision of the high bit data rates targeted in the broadband component of future wireless systems and a framework for the integration of heterogeneous wireless systems with fiber optics. The provision of high bitrates is by using Virtual MIMO, where each user terminal communicates simultaneously with multiple RAUs with perfect cooperation between them. In such scenario the fibre infrastructure provides a transparent transport network allowing the joint processing of the radio signals from the different multiple RAUs. In this respect the proposed architecture is advancing the state of the art in the area of convergence for next generation communications.

The mobility in the wireless systems brings dynamism in the propagation conditions and a variation of the cell load values as a consequence. In next generation wireless networks, several RATs may coexist in the same geographical area. The co-existense of multiple RATs that provide multiple applications/services for users with different QoS by multiple vendors with different service costs shows the need for efficient Local radio resource management (LRRM) and common radio resource management (CRRM) [2,3,4]. The CAC as part of the RRM functionality checks the admissibility of every new request or a request from handoff and allocates a RAT to the user in such a way that the QoS of the current user is satisfied and without degrading the QoS of already admitted users.

A number of CAC mechanisms have been proposed, based on fuzzy logic, fuzzy MADM, measurement-based and parameter-based. The measurement-based CAC takes the decision based on the current state of the network only; it has no prior knowledge about the traffic statistics. The parameter-based CAC uses the parameters of the resource and service to decide whether the network can accommodate a new connection. The fuzzy logic [7] has been proposed for use with CAC for decision making when large imprecise data is involved. The Fuzzy MADM based CAC [8] was used to combine different criteria e.g QoS, Price etc based on the weights for each criterion and to give ranking for all the alternatives. In [5], a two-tier CAC based on the call level and packet level performance metrics for 4G networks, was proposed. This algorithm, however, did not consider the mobility, while allocating a RAT. In [6], Olabisi discussed a fuzzy-logic based CAC where a two-stage CAC was proposed, with the first stage selecting the best cell for each RAT, and the second stage using a fuzzy MADM to select the best RAT depending on the capabilities of the RAT and the user weights for each capability. [6], however, did not consider the type of the call and the velocity of the user during the admission decision and RAT selection. In [7], Giupponi proposed a fuzzy-logic based CAC, where for each cell the signal strength, the resources available and the mobility of the user were taken into consideration for each RAT and the decision for each RAT was made based on the inputs for each RAT. The main problem in the approach was the

scalability. The number of combinations of input for 3 RATs in this approcah was 432, and for 5 RATs this number would be 15,552 combinations.

In [8], Zhang uses the fuzzy MADM approach for the network selection, which was based on price, bandwidth, SNR, sojourn time and seamlessness of the communication process. The fuzzy MADM method used in [8] operates in two steps. The first step is to convert the imprecise fuzzy variable into crisp values. The second step is to apply the classical MADM to combine the fuzzy variable and obtain ranking for each RAT. In [9] Chen used a fuzzy Q-learning based admission control (FQAC) for WCDMA/WLAN heterogeneous network. There, the admisison control was based on the number of users and the interference in WCDMA, and the network busy periods in WLAN. QoS based Q-learning provides the ability to adapt to the system dynamics and uses data rate, delay and BER.

This paper adopts the fuzzy logic approach and proposes a novel common CAC architecture that is applicable to a heterogeneous RAT scenario as shown in Fig.1. The algortihm selects the best RAT by taking into account the network status (e.g., load), the application requirements (e.g., data rate, latency, BER), the user parameters (e.g., velocity, signal strength). The paper is organized as follows. Section 2 describes the scenario architecture. Section 3 proposes the admission control algorithm for the scenario architetcure. Section 4 introduces the fuzzy-based Cell/RAT selection algorithm as part of the LRRM functionality. Section 5 proposes and evaluates the RAT selection algorithm at the CRRM level. Section 6 concludes the paper.

III. SCENARIO ARCHITECTURE

The scenario archirtecture shown in Fig.1 considers a hybrid fibre-radio network that interconnects multiple Remote Antenna Units (RAUs), transparently carrying radio signals to/from a Central Unit, where joint processing takes place as part of a next generation communications scenario. A generic architecture was proposed in [10] to serve a geographical area that is divided into several serving areas, where the multifrequency RAUs is located. These RAUs are linked to a Central Unit CU, using a transparent optical fibre system, and can send/receive signals from different wireless systems. Fig 1 shows the RAUs connected to a RoF manager, which manages the fibre optic links and the network.

LRRM is responsible for the local management specific to the RAT such as power control, scheduling etc. All LRRMs are connected to the CRRM. The CRRM is responsible for the global management of the resources through the LRRMs. The LRRM entity sends to the CRRM, a candidate cell list, together with measurements and the QoS requirements, and the CRRM entity selects the best target cell.
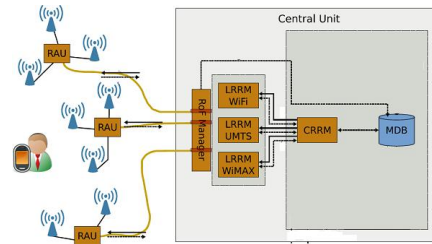

Figure 1: FUTON architecture with CRRM [10]

IV. PROPOSED CAC ALGORITHM

Fig 2 shows the stages of the proposed here CAC. The first stage of the algorithm selects the best cell in each RAT. The selection of the best cell depends on the received signal strength reported by the mobile, and the resources available in that cell. The cell selection is done by using a fuzzy logic controller [12] with inputs the signal strength and resources available. The output of the fuzzy logic controller is the cell admittance factor (CAF), which is based on the two inputs. The type of call is taken into consideration while deciding the output. Vertical handoff or horizontal handoff calls are given more priority than a new call.

The cell selection block is located inside the LRRM entity (see Fig. 2). LRRM can give an admission to the mobile based on the output from the cell selection algorithm or it can forward the request with the CAF values to the CRRM, which takes a decision based on the outputs from all LRRMs and the other criteria such as the user preferences etc.
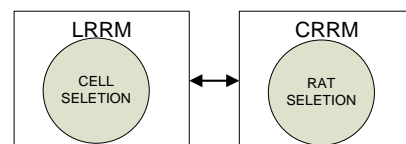

Figure 2: Proposed CAC in FUTON

Once the cell selection algorithm has selected the best cell in each RAT, the most appropriate RAT among the RATs whose selected cell meets the cell selection criteria is selected by the RAT selection algorithm. The RAT selection algorithm selects the best RAT depending on the application, QoS requirements, service cost of the RAT, and mobility of the user. Fuzzy MADM method is used to combine the above inputs and take the decision of finding the best RAT.

V. CELL SELECTION ALGORITHM

The cell selection algorithm works inside the LRRM, to select the best cell in each RAT. Fuzzy logic [12, 13, 14] is used to select the best cell based on the signal

strength (SS) and the resources available (RA) and the type of the call. Mamdani based Fuzzy logic controller [12] consists of Fuzzifier, Inference engine and Defuzzifier as shown in Fig 3.
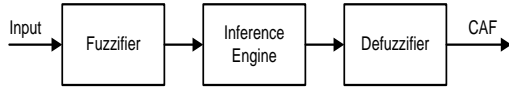

Figure 3: Fuzzy Membership functions [12]

The Fuzzifier assigns a degree of membership for each input value, based on the fuzzy set it belongs to and membership function for the linguistic variable in that fuzzy set. Each of the input variables is assigned in to a fuzzy set; for example fuzzy set values of SS consist of linguistic terms: Strong, Medium, and Weak. The universe of discourse for the fuzzy variable SS is defined from -100dBm to -80dBm. The universe of discourse for resources available is from 0% to 100%, and the fuzzy set values for RA consist of the linguistic terms Very Low, Low, High, Very high. The membership functions used for the above three variables are Triangular and Trapezoidal as shown in Fig 4. The output of the fuzzy logic controller is the cell admittance factor (CAF), which consists of the linguistic terms as No (N), Probably No (PN), Probably Yes (PY) and Yes (Y).

All LRRMs are connected to the CRRM. The CRRM is responsible for the global management of the resources through the LRRMs. The inference engine executes some predefined *if-then* fuzzy rules, referred to as inference rules and determines the decision to admit the new call or handoff call for each RAT. The predefined rules are shown in Table 1. The decision varies depending on the type of call. More priority is given to the Vertical/Horizontal handoff call than a new call.
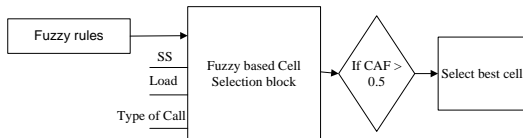

Figure 4: Cell Selection algorithm

The defuzzification involves the conversion of the fuzzy output in to the crisp output. There are many methods of defuzzifying the fuzzy output in to crisp value. Here, it is proposed to use the Centroid method [14]. The centroid defuzzification returns the center of the area under the curve. The output curves corresponding to each rule are added to get the final curve and then the centroid of the curve is found. Fig 5 shows the block diagram for cell selection algorithm.

For example, the specific fuzzy output that emerged from the composite fuzzy inference rule is $N = 0$, $PN = 0$; $PY = 0.2$ and $Y = 0.8$. Now the areas of PY and Y are combined and thus their contour becomes composite fuzzy output.

The cell selection algorithm inside the LRRM checks the signal strength received by the user from

that particular cell of the RAT, and checks the available resources in the cell and type of call before giving the decision. Then the decision is forwarded to CRRM where the CRRM checks the CAF for each RAT and other user criteria, and gives the best Cell and RAT to the user.
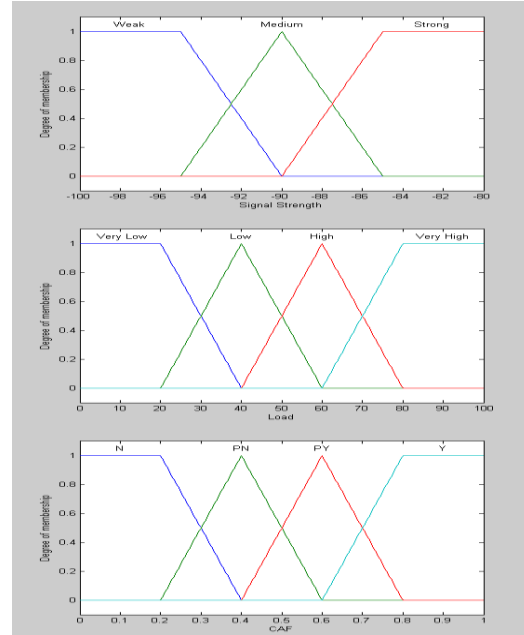

Figure 5: Fuzzy Membership functions

Table 1: Fuzzy inference rules for new/handoff call

Load	Signal Strength	CAF for new call	CAF for handoff call
VL	Weak	PN	PY
VL	Medium	Y	Y
VL	Strong	Y	Y
L	Weak	PN	PY
L	Medium	PY	Y
L	Strong	Y	Y
H	Weak	N	PN
H	Medium	PN	PY
H	Strong	PY	Y
VH	Weak	N	N
VH	Medium	N	PN
VH	Strong	N	PN

Defuzzification method computes the centroid of this area using (1).

$$\sum_{j=1}^{p} y_j \mu(y_j) / \sum_{j=1}^{p} \mu(y_j) \qquad (1)$$

where $\mu(y_j)$ is the area of membership function of *PY* and *Y* is modified (i.e clipped) by the fuzzy inference result and y_j are the positions of the centroids of the individual membership functions *PY* or *Y*.

VI. RAT SELECTION ALGORITHM

The RAT selection algorithm takes the best cells for each RAT from the Cell selection algorithm and decides the best RAT to the user based on the inputs from the user and the suitability of each RAT to the user needs. The parameters taken into consideration

for selecting the best RAT are the QoS parameters like datarate, latency and BER, mobility of the user and the service cost of each RAT. These parameters need to be combined in a way to find the best RAT as per the user preferences. For this Fuzzy MADM (Multiple Attribute Decision Making) method is used to combine the parameters. In this approach there are two stages, the first phase is to convert the fuzzy data to crisp values and the second phase is to apply the classical MADM to find the ranking order for every alternative.

There are many methods, such as the classical MADM methods such as SAW (Simple Additive Weighting Method), AHP (Analytical Hierarchical Process), TOPSIS (Technique for Order Preference by Similarity to Ideal Solution), DEA (Data Envelopment Analysis etc)[8]. The most popular approach is the SAW method. In this paper we illustrate RAT selection algorithm using SAW method.

SAW method consists of four parts, which are 1) Alternatives 2) Attributes 3) Weights for each attribute 4) measures of performance of alternatives with respect to attribute. If there are N alternatives each with M attributes and if w_j (for j=1,2..M) is the weight of the attribute and m_{ij} is the measure of performance (i = 1,2,…N; j=1,2..M) then the size of decision matrix is NXM. SAW method has to find the rank for each of the N alternatives using (2).

$$P_i = \sum_{j=1}^{M} w_j (m_{ij})_{normal} \tag{2}$$

where $(m_{ij})_{normal}$ is the normalized value of m_{ij} and P_i is the composite score of alternative Ai. The alternative with the highest value of Pi is considered as the best alternative [8].

The attributes can be of two types, beneficial and non-beneficial. For a beneficial attribute (e.g profit) its highest measures are required for given decision making problem. So the normalized value of m_{ij} is the ratio of each value with its highest attribute in N alternatives. For non beneficial attributes (e.g cost) where lower measures are needed for decision making the normalized value is the ratio of smallest attribute with each value.

$$m_{ij} = m_{ij}/m_{imax} \tag{3}$$

$$m_{ij} = m_{imin}/m_{ij} \tag{4}$$

In the RAT selection problem the number of attributes is five and the weights for each attibute are taken from the users input depending on the application requirements, QoS requirements for the applications, cost requirements for the user etc. Fig 6 shows the block diagram, which explains the RAT selection algorithm.

VII. PERFORMANCE EVALUATION

Consider a multimode terminal running two applications, voice and file download, needs handoff due to mobility and moving from one cell to another. Then, the user scans for all available cells and RATs. The user finds 3 UMTS cells (Au, Bu and Cu) and 3 WLAN cells (Aw, Bw, Cw). And the user initiates handoff by sending a request with all the networks found and their signal strengths, and QoS preferences for each application being run on the terminal like datarate, latency, BER and the service cost it needs and also its speed.

The QoS requirements for voice and file download are generally different. The voice application needs low data rate and low latency, while the file download needs high datarate and can tolerate more latency [15, 16]. The algorithm assigns a weight for each user criterion according to the QoS needs of the application. The weights assigned by the user for voice and file download are W_v and W_d respectively. Based on the inputs from the user and the network conditions, the admission control algorithm has to decide whether to admit the user into the network.
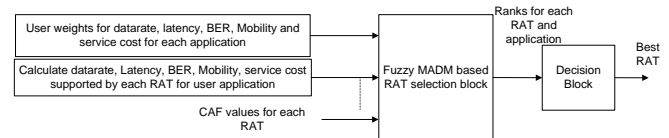

Figure 6: RAT Selection algorithm

If yes, then the cell and the RAT have to be allocated to the user as per the identified needs and network conditions.

In this example, the signal strength and load for UMTS in each cell Au, Bu and Cu are (-85, 25), (-80, 90), and (-95, 55). For the WLAN, the SS and load in each cell Aw, Bw and Cw for WLAN are (-85, 77.5), (-82, 20), (-90, 80), respectively. The CAF values for UMTS are 0.837, 0.4, and 0.458. For WLAN these values are 0.847, 0.482 and 0.4. Fig 7 is the plot showing the CAF curve based on sinal strength and load for handoff call.
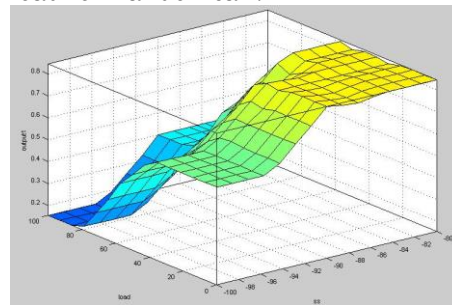

Figure 7: CAF plot for handoff call

From CAF values for each cell, the best cells in each RAT, Au and Bw are selected as CAF for Au and Bw are higher compared to other cells. These CAF values are forwarded to RAT selection algorithm in CRRM.

The RAT selection algorithm selects the best RAT based on the datarate ($mi1$), latency ($mi2$), BER ($mi3$), Mobility ($mi4$), price ($mi5$) and battery power consumption ($mi6$). The attributes of RAT1 and RAT2 corresponding to Au and Bw are as given in decision matrix D.

$$D = \begin{matrix} m_{i1} & m_{i2} & m_{i3} & m_{i4} & m_{i5} & m_{i6} \\ \begin{bmatrix} low & & low & medium & high & medium & 1 \\ veryhigh & low & low & & low & low & 0.5 \end{bmatrix} \end{matrix} \quad (5)$$

Since the user is running two applications voice and video, the preference for RAT selection are modelled as weights assigned by the user on each criteria, for voice as W_v and for file download as W_d

$$W_v = \begin{bmatrix} low & low & medium & veryhigh & medium & low \end{bmatrix} \quad (6)$$

$$W_d = \begin{bmatrix} veryhigh & medium & low & veryhigh & low & low \end{bmatrix} \quad (7)$$

The linguistic terms in decision matrix D are converted to the crisp values using the conversion scale from Fig 8, and D after conversion is

$$D = \begin{bmatrix} 0.283 & 0.283 & 0.5 & 0.717 & 0.5 & 1 \\ 0.909 & 0.283 & 0.283 & 0.283 & 0.283 & 0.5 \end{bmatrix} \quad (8)$$

The user preferences for voice and file download applications are converted in to crisp values and normalized so that the sum is equal to 1. The normalized weights for voice W_v and file download W_d are

$$W_v = \begin{bmatrix} 0.1026 & 0.1026 & 0.1813 & 0.3296 & 0.1813 & 0.1026 \end{bmatrix} \quad (9)$$

$$W_d = \begin{bmatrix} 0.2870 & 0.1579 & 0.0894 & 0.2870 & 0.0894 & 0.0894 \end{bmatrix} \quad (10)$$
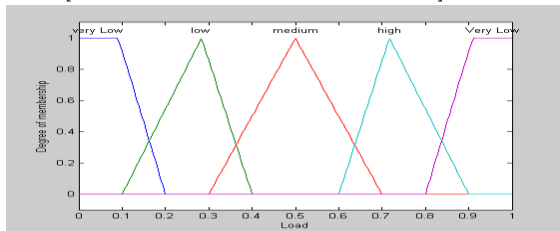

Figure 8: Linguistic term to fuzzy number conversion scale

The values in the decision matrix are normalized according to (3) for benefit and (4) non-benefit criteria. In this case mi1, mi4 are benefit criteria, mi2, mi3, mi5, and mi6 are non-benefit criteria. The normalized decision matrix is

$$D = \begin{bmatrix} 0.3113 & 1 & 0.5666 & 1 & 0.5666 & 0.5 \\ 1 & 1 & 1 & 0.3947 & 1 & 1 \end{bmatrix} \quad (11)$$

Applying (2) to decision matrix and weight matrices the final ranks for RAT1 and RAT2 for voice application are RAT1 = 0.7207 and RAT2= 0.8005. For the file download application, the ranks for each RAT are as follows: RAT1 = 0.6801 and RAT2 = 0.8263. For both voice and filedownload applications, the rank obtained by RAT selection algorithm for RAT2 is greater than RAT1, therefore, RAT2 is selected. The Overall rank can be obtained by taking the average, assuming equal weights for either applications, or the user assinged priorities can be user for each application. The overall rank for RAT1 is 0.7 and for RAT2 is 0.81. Then, the user is admitted in to Bw.

VIII. CONCLUSIONS

In this paper, we proposed call admission control algorithm that is suitable for FUTON architecture. This algorithm can be used for any next generation heterogeneous wireless network with multiple applications, and various QoS requirements from users. This algorithm gives more priority to the type of call, and handoff call is given more priority than a new call. Also the mobility is taken in to consideration while allocating RAT to the user, as different RATs supports different coverages, mobile speeds and fading scenarios for multipath channels.

The algorithm works in two stages, Cell selection stage and RAT selection stage. Fuzzy logic controller is used for cell selection and RAT selection problem is considered as decision from multiple attributes, for which fuzzy MADM approach is used. CRRM selects the best RAT out of available RATs, which best serves the user's requirements based on th input from the user. Apart from the user's preference, mobility is also taken in to consideration while deciding the RAT. Multi application scenario is taken in to consideration and suitable RAT is selected based on the rank obtained from fuzzy MADM that suits the Qos requirements of both applications.

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