Context-aware Multi-attribute Radio Access Technology Selection for 5G Networks

Swetha Indudhar Goudar[1,2], Adib Habbal[1], and Suhaidi Hassan[1]

***Abstract*- Abstract--- The 5G networks are an agnostic global single air interface with multi-Radio Access Technology (RAT) having a stronger interplay of communications, computing and control. Multi-RAT being one of the driving feature of the 5G networks with the dense deployment of the heterogeneous RATs. This feature resolves the issue of coverage for the user, but at the cost of system performance degradation due to the frequent handover between the RATs. The initiation and decision of handover between the RATs are based on the radio signal strength, an implied traditional approach. However, its not the adequate measure in the context of 4G/5G user-centric wireless networks, due to the numerous real-time applications populated with different metrics measuring the efficiency apart from the signal. Thus, the RAT selection needs to consider a multiple criteria with the context-awareness for efficient decision-making tailoring towards the future 5G networks. This paper proposes a Context-aware Multiple Attribute Decision Making (CMADM), integrating the Multiple Attribute Decision Making (MADM) methods, dynamically triggering the initiation and selection of RAT according to the context. CMADM method, the conceptual model is presented in this paper, aiming to obtain the better throughput with minimum delay during the RAT selection.**

Index Terms—5G networks, multi-radio access technology, context-aware.

I. INTRODUCTION

Rapid growth in the smart devices and usage of multi-media applications with superior expectations of user experience is pressing towards the future generation of wireless broadband technology, Fifth Generation (5G). According to the CISCO survey, growth is expected to intensify thousand fold by 2020 [1]. The notable trends driving the 5G era are Dense Networks (DenseNet), Multiple Radio Access Technology, Device to Device communication and Massive Machine to Machine communication. Dense Network is the close deployment of the base station and access points to enhance the coverage for the user.

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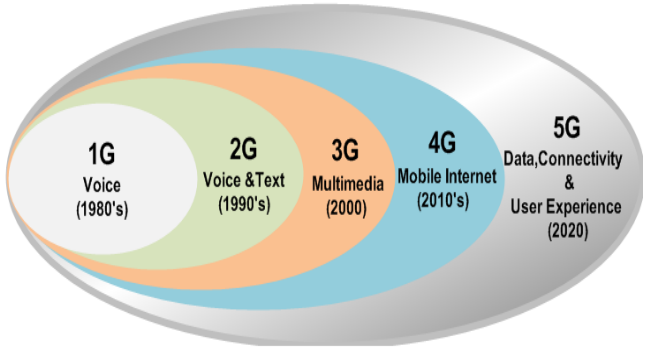

Fig. 1. Evolution from 1G to 5G [3]

The dense networks with multiple Radio Access Technology (RAT) enhances the cell capacity with co-ordinated heterogeneous network, with the improved front and backhaul technologies capable in terms of speed and deployment flexibility [2]. The network evolution since the First Generation (1G) is contemplating towards the better service with the best connectivity always. Figure 1 shows the evolution from 1G to 5G technology and the support of features in respective generation. The current generation comprising of heterogeneous RAT changes the “Anywhere, Anytime” paradigm, paving a way to enhance the contemporary wireless networks in the RAT selection with mobility.

The 5G technology being the single global air interface of all existing RAT enables mobile devices to make a choice among multiple RAT overcoming the drawbacks of single RAT. Heterogeneous networks, which is the integration of different RATs offers the flexibility for mobile devices to move across multiple RAT with varying strengths to cater numerous applications [4]. A transformation of mobile user experience requires revolutionary changes in both network infrastructure and device architecture, where the user equipment (UE) is jointly optimized with the surrounding network context]. Many believe that the only feasible solution to mitigate the increasing disproportion between the desired QoS and the limited wireless resources is by deploying higher densities of femto and macrocells in current cellular architecture. Due to shorter radio links, smaller cells provide higher data rates and require less energy for uplink transmission, especially in urban environments [5]. However, introducing an increasing number of serving stations to bridge the capacity gap incurs extra complexity due to more cumbersome interference management, higher rental fees, and

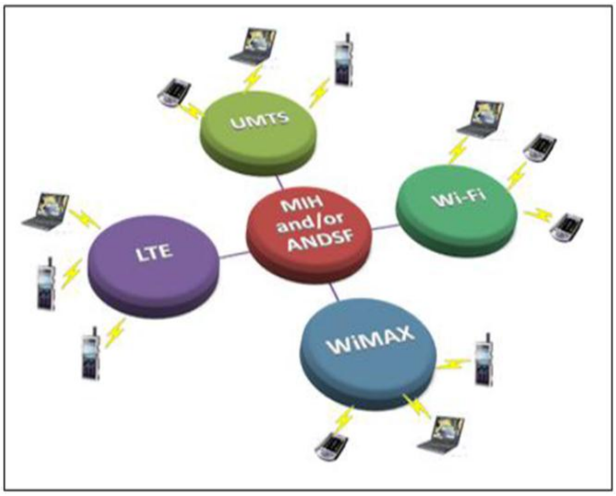

Fig 2 Multiple RAT Connected with Numerous Mobile Terminals [7]

increased infrastructure maintenance costs [6]. Two of the major challenges in RAT selection, management are seamlessness and automation aspects in the vertical handover across RAT.

RAT selection gains momentum, because of the availability of different wireless access networks interfaced to serve mobile terminals with multiple access interface feature. So, enhancing the selection of RAT for the combination of multiple RAT and multimodal interface in an ultra-dense environment is vital. Figure 2 depicts the multiple RAT connected to different mobile terminals. An appropriate selection of RAT in available RATs is very critical for optimum utilization of network resources with efficiency.

A numerous RAT selection approaches have been proposed for selecting appropriate RAT based on gathered information primarily focusing on Radio Signal Strength (RSS) and a few combine criteria like available bandwidth, power consumption and quality of service criteria [8]. However, the majority of these approaches is simply based on Radio Signal Strength (RSS) to make a handover, hardly very few which consider many criteria to initiate RAT selection. This instigation is an inadequate solution for the 5G networks due to the support of the plethora of new applications and horizontal views necessitating to consider more criteria rather than RSS and bandwidth only. Kaloxylos and Barmpounakis [9,10] proposed a mechanism for RAT selection in the 5G networks, still the emphasizes RSS only. But, a multi-criteria approach may yield better throughput and Quality of Service.

Hence, an appropriate, realistic mechanism based on the context along with multi-criteria is of the essence. A wrong selection of a RAT may result in a heavy burden on network infrastructure. Background studies do not reveal any approach of multiple criteria decision making with context awareness in the 5G technology. The literature reveals that most of the future wireless infrastructure should converge towards context-aware approach depending on the application requirement [11].

A good survey and analysis of different approaches to handle RAT selection issues are discussed and mainly highlighted the prominence of context-aware strategy as an efficient decision making in heterogeneous networks [12]. In the heterogeneity scenario combined with the multimodal network interface, initiation and decision making for RAT selection is very critical and need to be efficient in considering user preference and network availability with the context-awareness [13].

This paper is organized as follows. Section II describes RAT Selection Overview. Section III presents our access network selection technique, Context-aware Multiple Attribute Decision Making (CMADM) conceptual framework. Section IV concludes this paper.

II. RAT Selection Overview

RAT selection was fostered since the integration of diverse wireless network to achieve “Always Best Connected” paradigm with heterogeneity, along with integration and interoperability among the RATs [14]. Context is a concept in which system reacts dynamically to trigger an action based on the gathered information. In the context of multi-RAT environment mapping, the user devices with the available RAT is of the essence. Adnan et al. [15] made a survey of different approaches of decision making algorithm based on RSS, bandwidth and combined (RSS and bandwidth), concluding that current decision algorithms lack deliberation of various network parameters pertaining to the 4G/5G specifications. The open challenge is to formulate various parameters based on network context and user preference for intelligent decision making.

RAT selection comprises of three phases such as initiation, decision making and execution. Figure 2 represents the three phases of RAT selection.

Initiation: This is the first phase of RAT selection also known as information gathering, system discovery or system detection by different researchers. This is a process triggered based on measurement, analysis of the criteria to decide the need for the new Point of Association (PoA). The information about the each network is stored in the information database of the core network of each RAT and updated periodical to know the RAT availability to User Equipment (UE) for better service delivery to switch from the current serving RAT. Traditionally, RSS is the main criteria which initiate handover. But, due to the integration of different RAT and demand of UE choice, initiation not confined only to signal alone, this obligates in considering multiple criteria based on the context for the initiation. In short multiple criteria are accessed for handover initiation based on user preference and network capacity, depending on the measurement of the criteria and synthesize the initiation is confirmed.

Decision Making: It is the second and most crucial phase of the RAT selection procedure. The selection is done by the aforementioned priorities and preferences of the UE and network context, measured from the initiation phase. The

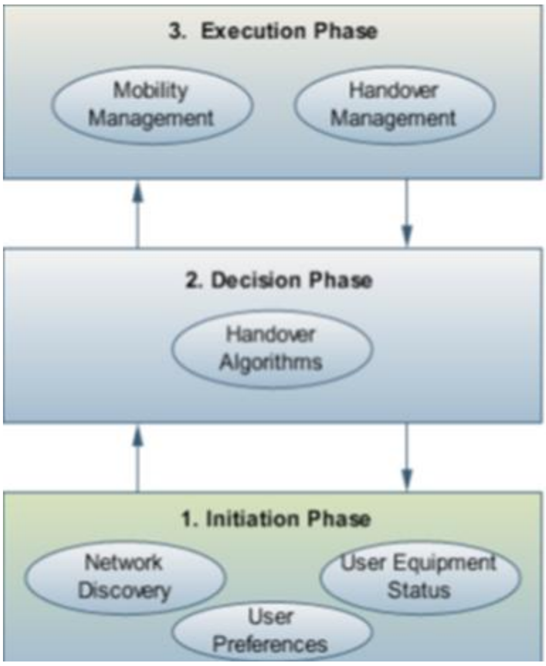

Fig 3. RAT Selection Phases

RAT selection decision is also known as network selection or system selection as it decides the next target RAT. The employed mechanism to analyze the criteria helps to decide the best choice of RAT. Decision making needs an intelligent mechanism to evaluate and decide based on the requirements for attaining the desired seamless communication.

Execution: This is the final phase of RAT selection, the new target PoA is chosen based on the previous two phases (initiation and decision making). After, logically processing multiple parameters, it necessitates to bind the UE to the selected network seamlessly. Execution is attached to new RAT, while releasing the old RAT.

A. RAT Selection Criteria

Literature reveals a lot of approaches for RAT selection, based on the preferences of application and network resource availability. The traditional approach primarily considers Received Signal Strength (RSS) for initiation and decision making, but its inadequate with heterogeneous networks serving with multiple RAT [16]. Hence, it's pressing towards more criteria considered in the initiation and decision making in RAT selection. Figure 4 lists the RAT selection criteria for initiating and decision making of the best RAT. Few main criteria pertaining to the network and user preferences are described below,

Received Signal Strength (RSS): It is one of the primary and mandatory criteria in switching the network. RSS is easy to measure and unswervingly related to the quality of service. It offers information about the strength or the power of the signal received from the Access Point (AP). The strength of the signal may be reduced as the UE moves away from the AP due to mobility. In order to maintain the connection without interrupting the service of the user, connection to other AP needs to be attained seamlessly.

Network Connection Time: It signifies the period, terminal remains connected to the AP. It is vital to trigger a handover at the right time to maintain a satisfactory quality of service. The role of network connection time is of principal importance in VHO decision due to the integrated RATs vary in their coverage.

Available Bandwidth: It notifies the available data communication resource expressed in bits per second (bit/s). Advantages in case of delay-sensitive applications, it actualities to be a good indicator of traffic conditions. In the instance of heterogeneous networks, it becomes the desperate factor due to the varying bandwidth offered by different RATs.

Power Consumption: It elongates the service with available battery. If the power is diminishing, quickly switch to the network which consumes less energy extending the battery life.

Monetary cost: Different networks, specify and employ different charging policies. Resulting in divergences of coverage, network conditions taking into account cost and QoS trade-offs. Hence cost also becomes a prime factor for decision making.

Security: A prime issue raised, especially when integrating different networks. Each network differs in their policies and user comply during the handover process. Congruent to all factors for achieving security in heterogeneous networks is unavoidable. The security level varies accordingly based on application confidentiality.

User Preferences: User preference would be based on available network, to execute or serve the application. Preference can be also defined based on application priority executed by the usage which is either high or low.

B. RAT Selection Initiation

The need to choose the new target RAT and the benefits of choosing the new access network are known as RAT selection initiation. This phase triggers the need for initiation for new PoA based on the system information. The information needs to be retrieved from core network architecture component. In Third Generation Partnership Project (3GPP), Access Network Discovery and Selection Function (ANDSF) serves as a core network repository. The information of criteria is updated periodically to know the RAT availability to User Equipment (UE). Traditionally RSS is the main criteria which initiate the handover from the current serving RAT. But due to the integration of different RAT and demand of UE choice initiation is not confined only to signal, obligating to consider multiple criteria based on the context information. ANDSF provides the information about the criteria for measuring the necessity for initiation.

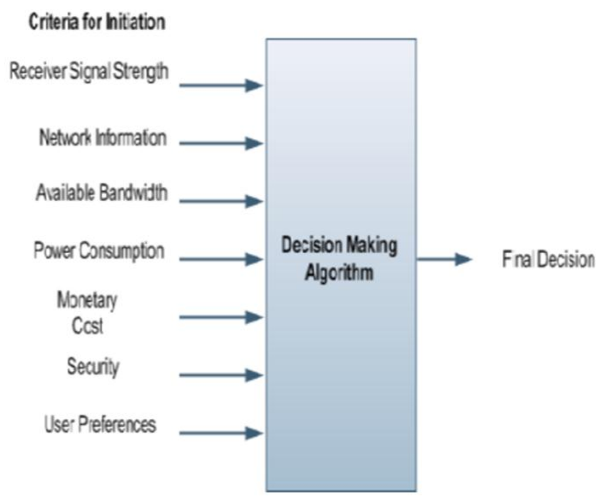

Fig. 4. Decision Criteria

Access Network Discovery and Selection Function (ANDSF)

ANDSF was proposed by the 3GPP in 2008 [17]. ANDSF is a core network entity defined in 3GPP standard TS23.402 [3GPP], that contains functionalities of data and control management between the User Equipment(UE) and operator services. The updating of the network information is dynamic with the interface provided by the Evolved Packet Core (EPC) architecture in between UE and network by 3GPP. The EPC easily coordinates with the 3GPP and non-3GPP access networks to make network information available to UE. Hence, the primary functionality of the ANDSF component is to provide the UE with the network information when it moves across heterogeneous networks. The advantage of ANDSF is the dynamic construction of the database, serving as the information repository. The RAT initiation measurement of the network can be attained from the ANDSF repository depending on the context of the user and network preferences.*Equations*

C. RAT Selection Decision Making

The initiation phase triggers the need for new PoA based on the shortlisted criteria analyzes. Further, decision making phase should analyze the criteria of all the available RATs and find the best RAT among the available RAT. Several approaches of RAT selection based on different criteria in the literature are reviewed in this section.

Radio Signal Strength based algorithms are the traditional and simpler approach to determine the handover. The current Access Point (AP), RSS is measured to compare with the predefined threshold. If the current RSS value compared to new RSS is greater than or equal to the defined threshold, it will resume the same AP else will initiate RAT selection [18]. Mohanty and Akyildiz [19] proposed a handover decision algorithm between WLAN and 3G on the basis of RSS value comparison also. Yan et al. [20] designed algorithm based on to reduce false handover initiation and failure probabilities but resulted to waste network resources with increased handover failure. A similar approach of dynamically calculating for RSS values to initiate handover between two networks resulted in wastage network resources with increased handover failure. With the increase in the diverse real-time application, RSS fails to be the adequate choice in initiating RAT selection.

The Quality of Service (QoS) based algorithm, combined the RSS and Signal Inference to Noise Ratio (SINR) in initiating the RAT selection enhancing the system throughput [21]. Few QoS algorithms combine the RSS with available bandwidth in deciding the appropriate RAT. QoS algorithms focused much towards user preferences while network criteria are over looked. In order to have a better analysis more than two criteria was considered to tailor the decision towards future wireless networks.

Multiple Attribute Decision Making (MADM) algorithms are mathematical optimization approach in realizing the RAT selection. The MADM approach calculates the quantitative value for criteria with the assigned weights to evaluate the target RAT [22]. There are few classic MADM approaches like Simple Additive Weighting (SAW), Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) and Analytic Hierarchy Process (AHP) for computing the best RAT, while analyzing the shortlisted criteria. SAW approach, employs the linear additive function to determine the preferences in decision making. The TOPSIS measures the relative efficiency among the available alternatives, accounts the limited inputs and ranks based on the closeness towards the ideal solution. Depending on the closeness it calculates the positive and a negative ideal solution towards the decision making. TOPSIS carefully chooses to target network, which is probably to be adjoining ideal solution and distant from the worst case solution among the available alternatives. However, TOPSIS fails to consider the intense relation between the criteria at different levels. Analytic Hierarchy Process (AHP) algorithm, is a computational approach that divides the problem into sub-problem and analyzes the initiation and decision making to choose the new RAT [24, 25]. AHP considers multiple criteria with the hierarchical approach to maintaining the importance of each criterion at different level enhancing the overall decision making. MADM approaches yield better results, however, to make a dynamic decision the context is vital.

Context-aware (CA) algorithm is based on the environment of the network and the user. The context-aware framework contains two tasks, namely managing context repository and evaluating context information, eventually help in handover decision making. Balasubramaniam et al. [26] showed the use of context-aware of pervasive computing. Literature exposes context-aware decision making employed by different researchers in diverse ways, combining with MADM technique for efficient decision making. Vaidya et al. [27] employed context-aware with AHP to make a choice among multiple alternatives with predefined objectives considering both network and user context. Context-awareness is nothing but the context in which the decision need to be taken to assess all the criteria. Thus, hybridizing two approaches would enhance the decision making.

The integration of methods for initiation and decision making with context is required for the user-centric 5G networks. In this paper, a conceptual framework of combining MADM with the context-aware mechanism is proposed. The background literature reveals, MADM and context-aware is the better approaches in heterogeneous networks for efficient and flexible decision making with reduced complexity.

III. CONTEXT-AWARE MULTIPLE ATTRIBUTE DECISION MAKING (CMADM)

CMADM is a hybridization of two approaches, aiming to make a better RAT selection capturing the advantage of both the method. Context presents the information about the current environmental criteria in initiating and decision making of RAT selection, while the MADM will provide the analysis of multiple criteria in the desired context for the initiation and decision making of RAT selection. The whole process of CMADM conceptual framework is explained in this section.

The user equipment is connected to the current RAT, initiation of RAT selection is triggered due to the various condition like fading signal, not meeting the required quality of service standard or any of the listed criteria standards based on user and network preferences. The MADM method infers the computation of the RAT Initiation Factor (RIF), determining the RAT initiation necessity. RIF is computed by applying the MADM approach to the criteria, weights are assigned according to the importance of each criterion and a pairwise matrix is composed. The mathematical computations based on the employed MADM method is implied to the composed matrix and the RIF is calculated. The RIF is compared with the threshold value set of the criteria by the standards that determine the intensity to choose initiation towards new target RAT. The RIF, computation considers the contextual information of both the user and the network in the initiation of RAT selection.

Once the initiation is triggered, the next phase is to decide the best RAT among the available RATs depending on the context information. The MADM method is used to rank the alternatives, the one with the highest rank is chosen to be the best one. In the initiation phase, the criteria are compared against the criteria in the pairwise matrix, whereas in decision phase criteria are compared with the available alternative RAT to generate a rank. Hence, a new pairwise matrix for ranking the RAT is calculated, according to the employed MADM approach methodology. The rank decides the next PoA. If there is an issue to attach the user equipment to the new PoA, the mechanism considers the next RAT in the rank vector as a better choice. The clear flow of the initiation and

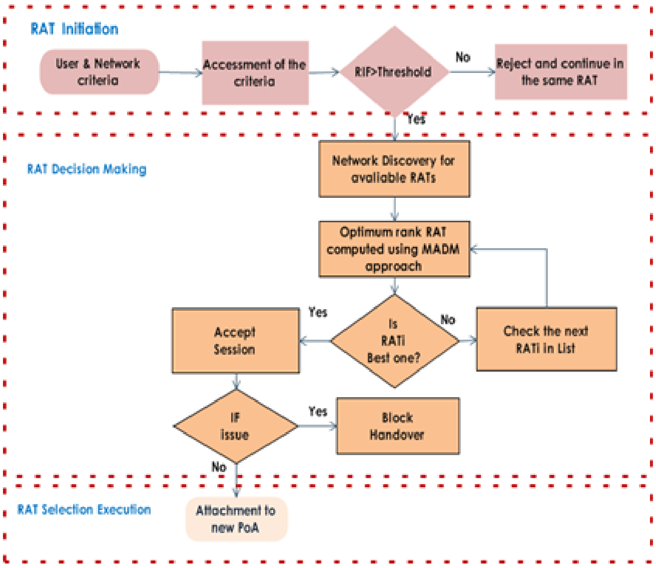

Fig 5. Conceptual Framework of CMADM Mechanism

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Begin
  Input the user and network parameter for RAT selection Initiation.
  Analyse the parameter using context-aware MADM to measure
  the neccessity of new point of attachment,compute RIF.
  if (RIF > threshold) than
              Network discovery for avaliable RAT.
  else
              continue in the same RAT.
  Rank the RAT using the MADM approach
          While
                    RATi with highest rank is choosen.
                    if (RATi is best)
                     PoA is RATi
            else
                     select the next RATi from the list.
          do(i) /* i is the number of RAT in list*/
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Algorithm 1: Pseudocode for CMADM

decision making to choose the best RAT process flow is represented in Figure 5 and the pseudocode in Algorithm 1.

The validation and verification of CMADM mechanism are done implicitly by the employed MADM computations iteratively. The methodology involves several computations to check the weights consistency at each step before arriving at the final rank. In general, several assumptions need to be made in order obtain the precise values for decision making, however, this hypothesis attempts to deal with the complexity of the future 5G networks new service and management requirements.

IV. CONCLUSION

In this paper, Context-aware Multiple Attribute Decision Making (CMADM) approach for RAT selection in the 5G networks is proposed. The proposed mechanism focuses on the initiation and decision-making phases of the RAT selection, considering the context of user and network preferences. The initiation and decision-making employ different MADM methods to quantify the necessity of changing the current RAT to the alternative new RAT.

The main contribution of this proposed research is to integrate context-awareness concept with multiple attribute decision-making an approach in the RAT selection of the 5G wireless networks. The method of combining the well-known MADM techniques with a context-aware decision is good in terms of efficiency, flexibility and complexity of implementation. A conceptual framework of hybridizing context-awareness and MADM methods is presented in this paper. Future work will explore the concept in the real network environment.

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