Radio Resource Management for Next Generation Wireless Networks

Abolfazl Mehbodniya and Fumiyuki Adachi

Graduate School of Engineering,
Department Communications Engineering,
Tohoku University
6-6-05 Aza-Aoba, Aramaki, Sendai 980-8579, Japan
Email: mehbod@mobile.ecei.tohoku.ac.jp adachi@ecei.tohoku.ac.jp

***Abstract*—With the rapid growth of wireless industry and related infrastructure, the demand for bandwidth is increasing exponentially and the initial works for designing the next generation (5G) mobile communications which accommodates a higher capacity has started. On the other hand, Energy is becoming a scarce resource and the need to optimize energy consumption in all industries as well as wireless industry is apparent. This paper aims at reviewing these issues by designing energy-efficient RRM modules for 5G heterogeneous networks (HetNet).**

***Index Terms*—WLAN, WMAN, WWAN, Network Access Selection, Vertical Handover, Heterogeneous Networks, FTOPSIS, energy-efficiency.**

I. Introduction

This research jointly addresses two major issues which are supposed to remain the main concerns of the worldwide research community for at least a decade; (1) Optimization of energy consumption to save the limited energy resources and cope with its increasing demand as well as reducing the worldwide CO2 emission, (2) The need for next generation (5G) mobile communications due to the tremendous trend in increase of data traffic. In this section we introduce the future challenges for 5G mobile communications and the need to revise the conventional design techniques for wireless communications in order to address the important energy-efficiency issue. Later, we review the available literature.

Information and communication technology (ICT) has significantly paved the way for a life with higher standards and quality. However, by current trends, ICT data traffic (mainly caused by Video transmission) is expected to increase 1,000 fold by 2020 and we will have at least 50 billion Internet-capable devices by that time. Due to this increased demand for bandwidth, we are running out of radio space sooner than expected and this is an alarm for a breakdown which may affect the nation's economy. For instance, smaller industries are dependent for wireless-enabled technologies, for their products and services. If a solution is not found for this high demand of bandwidth, instead of the flourishing of the new commercial opportunities, we'll witness a closing down. This is why 5G is so important, even before 4G has taken off. Unlike its predecessors, 5G does not only look for improving speed of data rates, but also tries to establish sustainability and making a global digital life a possibility. Early works on securing budgets and research works on 5G has started, e.g., European Commission has recently invested 50 million Euros into 5G research with a 2020 target [1]. Similar investments is reported in USA and UK and this signifies the urgency to start the same motion in other countries. Technically speaking, 5G mission will be to develop a spectrum- and energy-efficient network which is capable of reaching speeds of 10 Gbps. Specifically, its capability to minimize the energy requirements of web devices and network infrastructure is of utmost importance due to recent concerns for energy consumption in ICT industry.

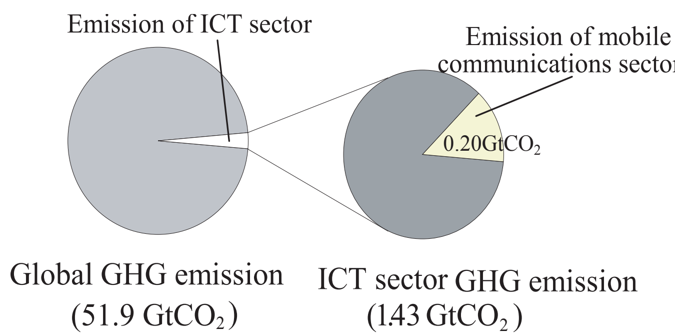

Fig. 1. Greenhouse gas emission of the Mobile communications sector in 2020.

With the rapid growth in the mobile communications sector, the carbon footprint of the ICT sector will grow up to 1.43 Giga-tons by 2020 (Fig. 1) and mobile communications sector is responsible for 201 Mega-tons of emissions by 2020 (14% of the whole ICT sector). A conventional macro base station (BS) consume 80% power of the telecommunication network and there exists a need to reduce it in order to mitigate the CO2 footprint and cope with the environmental effect and the financial issues associated with the increased prices of energy in the future. Already, EU targets a 20% reduction in the energy consumption of IT industry by 2020 [2]. First global initiative for reducing power consumption in wireless networks was the Green Radio (GR) project by Mobile Virtual Centre of Excellence (VCE) Visions group [3]. The GR project targets energy reduction from two different perspectives. The first is to find alternatives to the existing cellular network structures to reduce energy consumption. The second approach is to look for new ways that can be used in BSs or mobile sets (MSs) to reduce energy consumption in the network. As stated in the above, we need to address the 5G design issue from energy-efficiency (EE) perspective for both up link and down link communication. In particular, we should develop energy-efficient radio resource management (RRM) modules for HetNet 5G communications with the aim of improving the total capacity. HetNet network deployments (Fig. 2), i.e., the integration of macro and micro/pico/femto cells with different coverage, have already been approved as a working item in long term evolution (LTE)-advanced and 5G to overcome the increasing capacity and coverage demands, as well as to reduce the power consumption. Research activities for EE system design in modern wireless communications is scarce and in the initial state. During last decade most researchers have focused on spectrum-efficiency (SE), and EE was not considered by 3GPP as an important performance indicator until very recently. As a result recent wireless standards such as LTE (Fig. 3) have near optimal SE, with the aid of some advanced techniques such as turbo coding, while they ignore the EE issue. The main problem is how to balance EE and SE metrics in RRM module design, because they are usually not consistent and sometimes conflict with each other. A detailed study of such trade-off is also needed. Another issue is considering the electronic circuits' power consumption in the design. Most recent research works only consider the effect of transmission power consumption in their design and ignore the electronic circuits power consumption. As we see in Fig. 4 circuit power consumption especially in idle mode is also a considerable value. Ignoring this factor changes the equation and the overall performance will no longer be optimized.

In [4] the challenges for EE of next generation wireless communications is discussed. Authors in [5] proposed an energy-efficient RRM technique for orthogonal frequency division multiple access (OFDMA) networks. However, this work considers only the homogeneous network without assuming the communication interference. Interference is one of the main issues of concern in HetNet. Recently we fulfilled a preliminary study on target network selection in HetNet,

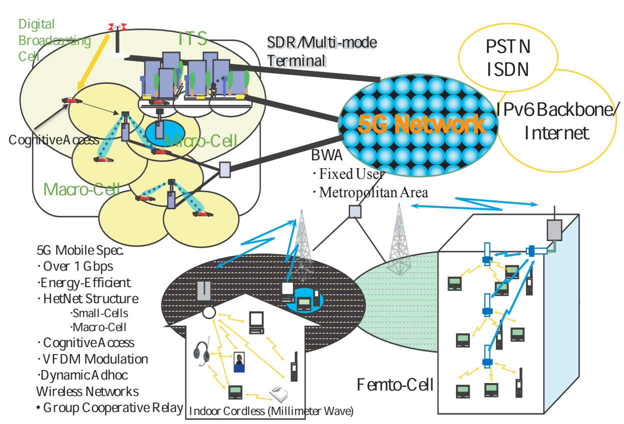

Fig. 2. 5G Heterogeneous (HetNet) Wireless Networks.

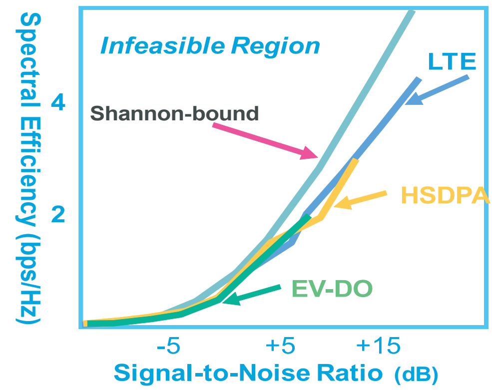

Fig. 3. Spectral efficiency of wireless standards.

which we are going to explain in the next section. In this study, we have optimized our algorithm from SE and user preferences point of view. In the future we intend to optimize our aforementioned proposed technique for EE.

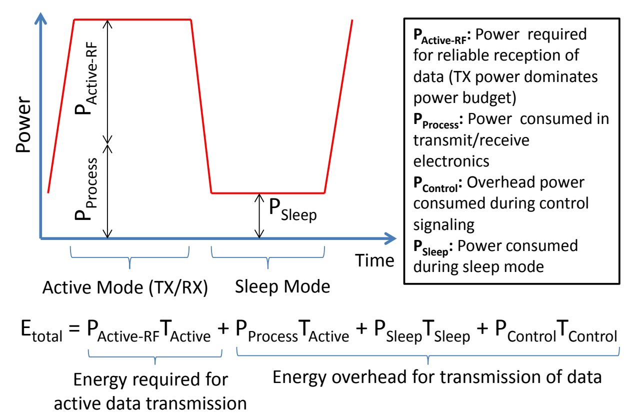

Fig. 4. Total wireless energy consumption at a BS.

II. Speed Dependent Handover Management and EE Enhancement.

To this end, a fuzzy-logic based technique is introduced, which takes factors such as received signal strength, QoS requirements, load conditions of different cells, and UE velocity into account, and ranks the candidate cells based on some optimality criteria.

The simulated topology is summarized in Fig. 5. It considers a HetNet structure with three layers: wireless local area network (WLAN), wireless metropolitan area network (WMAN), and wireless wide area network (WWAN). These terms are chosen only to differentiate layers with different coverage and technology, and can be easily extended to match the specifications of any standard. In this scenario, a multi-criteria vertical handover (VHO) scheme (Fig. 6) consisting of two modules is considered, namely, VHO necessity estimation (VHONE) and target layer selection.

The VHONE module examines the existing conditions of current point of attachment (PoA) to estimate the necessity of handover using Fuzzy Logic. The target layer selection module

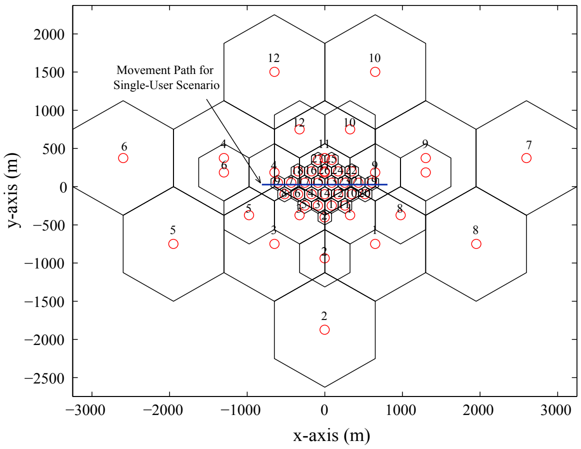

Fig. 5. Layered topology.

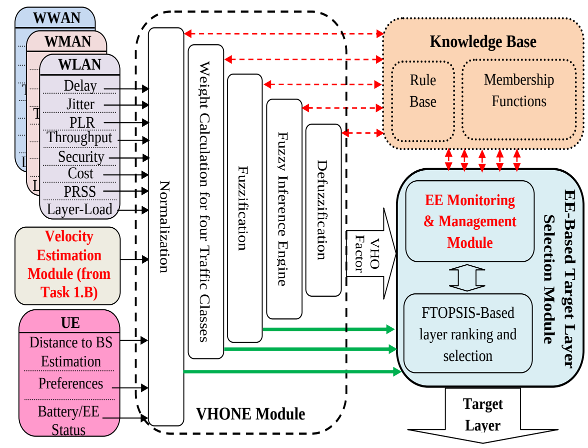

Fig. 6. Multi-criteria VHO scheme.

utilizes a *fuzzy technique for order preference by similarity to ideal solution* (FTOPSIS) algorithm to rank different wireless technologies based on multiple criteria in the order of priority. The proposed scheme considers four different types of traffic classes with different characteristics and QoS demands as defined by 3GPP TS-23.107 specifications [6]. Two levels of criteria are considered. The order of preference for level-1 criteria is given by: predicted received signal strength (PRSS), quality of service (QoS), *UE velocity*, layer-loading, security, and cost. The relative importance for the first-level criteria can be assigned by the UE whereas the relative importance for the second-level attributes, i.e., layer-throughput, latency, jitter and packet loss ratio (PLR), is defined by the scheme. Different requirements for the QoS of the traffic classes are also taken into account. The fuzzy calculation of weights, their priorities and the design details of the VHONE module are detailed in [7], [8].

To find the target layer for future connections, we rank the available layers in range based on the fuzzy version of a ranking algorithm called TOPSIS. The steps of the ranking process are as follows:

$$\mu(x) = \begin{cases} \frac{(x-l)}{(m-l)} & x \in [l, m] \\ \frac{(u-x)}{(u-m)} & x \in [m, u] \\ 0 & Otherwise \end{cases} \tag{1}$$

1) *Formation of Committee of Decision Makers*: A committee of k decision-makers is formed where fuzzy ratings of alternatives and weights of criteria obtained from each decision maker D_k can be represented as triangular fuzzy number (TFN) $\tilde{x} = (l,\ m,\ u)$, with the membership function given in (1). Here, m is the most promising value as it gives the maximal grade of the membership function $0 \le \mu(x) \le 1$, and l and u are the lower and upper bounds that limit the field of the possible evaluation.

$$\tilde{D}_k = \begin{array}{c c} & \begin{array}{cccc} C_1 & C_2 & \cdots & C_n \end{array} \\ \begin{array}{c} A_1 \\ A_2 \\ \vdots \\ A_m \end{array} & \left[\begin{array}{cccc} \tilde{d}_{11} & \tilde{d}_{12} & \cdots & \tilde{d}_{1n} \\ \tilde{d}_{21} & \tilde{d}_{22} & \cdots & \tilde{d}_{2n} \\ \vdots & \vdots & \cdots & \vdots \\ \tilde{d}_{m1} & \tilde{d}_{m2} & \cdots & \tilde{d}_{mn} \end{array} \right] \end{array} \tag{2}$$

2) *Fuzzy Decision Matrix Construction*: This step is the same as the classical TOPSIS with the exception that the ratings of all attributes are represented as TFNs instead of crisp values according to $\tilde{D}_k$ given in (2), where $\tilde{d}_{ij}$ is the fuzzy performance rating of the alternative A_i with respect to the criterion C_j, provided by the k^{th} decision maker and is expressed as a linguistic variable or TFN.

3) *Aggregation of Ratings and Weights from k Decision Makers*: The fuzzy ratings of alternatives and fuzzy weights of each attributes, obtained from k decision makers, are aggregated according to $\tilde{D} = (d_l, d_m, d_u)$ and $\tilde{W}_j = \left(w_{jl}, w_{jm}, w_{ju}\right)$. The variables in $\tilde{D}$ and $\tilde{W}$ are given by $d_l = \min_k\left(d_l^k\right)$, $d_m = \frac{1}{K}\sum_{k=1}^{K} d_m^k$, $d_u = \max_k\left(d_u^k\right)$ for $k = 1, 2, ..., K$, and $w_{jl} = \min_k(w_{jl}^k)$, $w_{jm} = \frac{1}{K}\sum_{k=1}^{K} w_{jm}^k$, $w_{ju} = \max_k(w_{ju}^k)$ for $k = 1, 2, ..., K$, where d_l, and d_u are the lower and upper bounds of matrix element d, represented by a TFN. The lower and upper bounds of the TFN representing the weight of the j^{th} attribute are denoted by w_{jl}, and w_{ju}.

4) *Fuzzy Decision Matrix Normalization*: Normalization may or may not be necessary depending upon the linguistic variables and their corresponding TFNs. In most cases the fuzzy decision matrix is already normalized since the TFNs belong to the range [0, 1]. Let's assume $\tilde{r}_{ij} = (\tilde{r}_{ijl},\ \tilde{r}_{ijm}, \tilde{r}_{iju})$ to be the TFN of the normalized value of alternative i with respect to attribute j. In case the normalization is necessary, a linear scale transformation may be used as follows:

$$\begin{aligned} \tilde{r}_{ij} &= \left(\frac{\tilde{r}_{ijl}}{b_j^*}, \frac{\tilde{r}_{ijm}}{b_j^*}, \frac{\tilde{r}_{iju}}{b_j^*}\right) \qquad b_j^* = \max_i \tilde{r}_{iju} \qquad j \in B \\ \tilde{r}_{ij} &= \left(\frac{c_j^-}{\tilde{r}_{iju}}, \frac{c_j^-}{\tilde{r}_{ijm}}, \frac{c_j^-}{\tilde{r}_{ijl}}\right) \qquad c_j^- = \min_i \tilde{r}_{ijl} \qquad j \in C \end{aligned} \tag{3}$$

where B and C are the sets of *benefit* and *cost* based criteria, respectively.

5) *Weighted Normalized Decision Matrix Construction*: This matrix is constructed by multiplying each element $\tilde{r}_{ij}$ with its associated weight $\tilde{w}_j$ according to $\tilde{v}_{ij} = \tilde{r}_{ij}\tilde{w}_j$:

6) *Calculation of Fuzzy Positive & Negative Ideal Solution*: The fuzzy positive and negative ideal solutions,

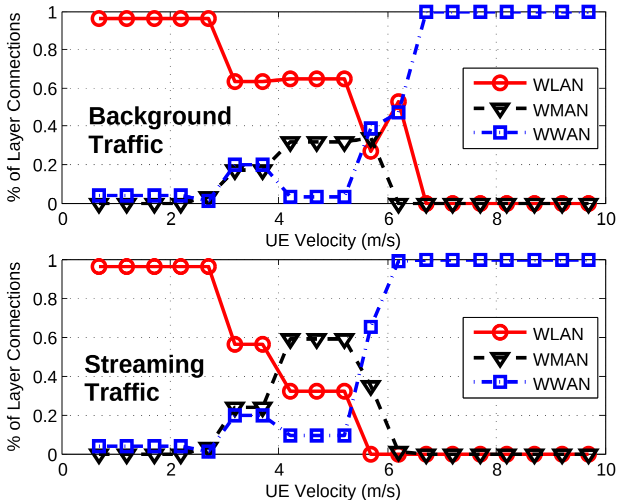

Fig. 7. FTOPSIS percentage of layer connections considering *background* and *streaming* traffic.

$\tilde{A}^+$ (FPIS) and $\tilde{A}^-$ $(FNIS)$, respectively, are defined as:

$$\tilde{A}^+ = (\tilde{v}_1^+, \ \tilde{v}_2^+, ..., \ \tilde{v}_n^+) \qquad \tilde{v}_j^+ = \max_i v_{iju} \tag{4}$$

$$\tilde{A}^- = (v_1^-, \ v_2^-, ..., \ v_n^-) \qquad \tilde{v}_j^- = \min_i v_{ijl} \tag{5}$$

where $\tilde{v}_j^+$, and $\tilde{v}_j^-$ are the maximum and minimum ratings of the alternative with respect to the j^{th} criterion.

7) *Calculation of Separation between Alternatives & Fuzzy Ideal Solutions*: The separation (distance) between each alternative from the fuzzy positive ideal and fuzzy negative ideal solutions are: $d_i^+ = \sum_{j=1}^n d_v(\tilde{v}_{ij}, \tilde{v}_j^+)$ and $d_i^- = \sum_{j=1}^n d_v(\tilde{v}_{ij}, \ \ \tilde{v}_j^-)$ for $i = 1, \ 2, ..., m$, where $d_v(*, *)$ is the distance measurement between two fuzzy numbers given by the vertex method as $d_v\left(\tilde{A}, \tilde{B}\right) = \sqrt{\frac{1}{3}[(a_l - b_l)^2 + (a_m - b_m)^2 + (a_u - b_u)^2]}$.

8) *Calculation of Relative Closeness to the Ideal Solution*:This step involves calculating the Closeness Coefficient (CC) or relative closeness to the fuzzy ideal solutions according to $CC_i = \frac{d_i^-}{d_i^- + d_i^+} \qquad i = 1, 2, ..., m$.

9) *Ranking of the Alternatives*: The ranking of the alternative is performed by sorting the values of relative closeness CC_i, in descending order. The best alternative has the highest value of CC_i, where alternative A_i will be closer to $\tilde{A}^+$ and farther from $\tilde{A}^-$, as CC_i approaches 1.

To show the performance of the proposed VHO algorithm, a single-user scenario is considered where one user moves along a straight path as shown in Fig. 5. Table I shows the numerical values chosen for system attributes at each layer. Fig. 7 depicts percentages of connections towards a preferred layer selected by the proposed FTOPSIS scheme for different UE velocities and *background* traffic. FTOPSIS shows higher preference towards WLAN for UE velocities up to 6 m/s. WMAN with 37% connectivity preference can be observed as the second choice for UE velocities up to 6 m/s, whereas 100% connectivity preference is shown for WWAN at higher speeds. Similar results for *streaming* traffic is also shown in Fig. 7. We observe that the percentage of layer connections for WMAN for a UE with medium velocity is around 60%. The *streaming* traffic requires a higher throughput. As can be seen from this figure, WLAN and WMAN fulfill this requirement for lower and medium UE velocity, respectively.

TABLE I
NETWORK PARAMETERS.

	WLAN	WMAN	WWAN
Delay (ms)	130	30	10
Jitter (ms)	30	10	1
PLR (per 10^6 bytes)	5	4	2
Throughput (Mbps)	140	50	0.2
Security (1-10)	5	5	5
Cost (1-10)	2	4	7

III. CONCLUSION

A Vertical Handover (VHO) algorithm with two modules, namely, VHO Handover Necessity Estimation (VHONE), and Target Network Selection, were proposed. The Fuzzy Logic based VHONE module determines whether a handover is necessary by taking into consideration the predicted RSS values provided by the current point of attachment (PoA), the degree of the provided QoS based on the requested traffic class (conversational, streaming, background, and interactive), and the speed of the vehicle including the MS direction of mobility. The target selection module also utilizes fuzzy logic in addition to a FTOPSIS ranking algorithm and a novel weight elicitation technique that are implemented to select the best target network. Preliminary results encourage the use of fuzzy logic techniques for cell/layer selection of devices in next-generation and emerging dense HetNet. In the future research we will extend these preliminary results and introduce flexible and multi-criteria fuzzy logic based algorithms for energy-efficient radio resource management in 5G.

REFERENCES

[1] "Engadget news agency," Feb. 2013. [Online]. Available: www.engadget.com/2013/02/26/european-commission-invests-50-million-into-5g-cellular-research
[2] "Smart 2020 report: Enabling the low carbon economy in the information age." [Online]. Available: http://www.smart2020.org/
[3] "Green radio project : Mobile virtual centre of excellence (vce) visions group." [Online]. Available: http://www.mobilevce.com/green-radio/
[4] Y. Chen, S. Zhang, S. Xu, and G. Li, "Fundamental trade-offs on green wireless networks," *Communications Magazine, IEEE*, vol. 49, no. 6, June 2011.
[5] C. Xiong, G. Li, S. Zhang, Y. Chen, and S. Xu, "Energy-efficient resource allocation in ofdma networks," *Communications, IEEE Transactions on*, vol. 60, no. 12, pp. 3767–3778, December 2012.
[6] J. Rinne, "3GPP specification details, ts 23.107."
[7] F. Kaleem, A. Mehbodniya, K. Yen, and F. Adachi, "Application of fuzzy TOPSIS for weighting the system attributes in overlay networks," in *14th Asia-Pacific Network Operations and Management Symposium (APNOMS)*, 2012, pp. 1–6.
[8] F. Kaleem, A. Mehbodniya, A. Islam, K. Yen, and F. Adachi, "A fuzzy preprocessing module for optimizing the access network selection in wireless networks," *Advances in Fuzzy Systems*, p. 9, 2013.