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Minimizing Battery Consumption in Mobile Device To Device and Spectrum Sharing Network: An Approach

Vera Ilenikhena
Department of Telecommunication Engineering
Federal university of Technology, Minna
Niger staigeria
ilenikhena.pg824484@st.futminna.edu.ng

Joshua Abolarinwa
Department of Telecommunication Engineering
Federal University of Technology, Minna
Niger State, Nigeria
j.abolarinwa@futminna.edu.ng

Michael David
Department of Telecommunication Engineering
Federal University of Technology, Minna
Niger State, Nigeria
mikeforheaven@futminna.edu.ng

***Abstract*— Power optimization in Device to Device networks has been studied using different approaches in literature which include allocation of resources (bandwidth and power) as well as Interference mitigation. However, in this paper, we propose a first exact modelling of several network parameters and their interaction in order to minimize the energy consumption in a Device to Device and Spectrum Sharing network. An optimization algorithm to also satisfy users with adequate quality of service while minimizing the Transmit power and achieving overall system Energy Efficiency is being proposed. With the proposed algorithm in this work, power level requirement for communication would be minimized without compromising the quality of service, therefore making the entire system energy efficient which is a metric for green communication.**

Keywords— Primary Transmitter (PT), Secondary Transmitter (ST), Device to Device (D2D), Energy Efficiency (EE)

I. INTRODUCTION

The evolving 5G wireless network is anticipated to support up to1000-fold increase in capacity compared to existing network [1]. This evolution of information and communication technology (ICT), is expected to come with a drawback in terms of high energy usage. This increase in energy consumption will affect the network operator by reducing the Energy efficiency of the system and increase operational cost. It will also lead to environmental issues such as increased Greenhouse gases in the atmosphere [2]. From a user Quality of Experience (QoE) perspective, it has been shown that more than 60% of mobile users complain about their limited battery capacity [3]. The gap between the demand for energy and the Mobile Terminal (MT) offered battery capacity is increasing exponentially with time. Hence, the mobile terminal operational time between battery charging has become a significant factor in the user perceived quality-of-service (QoE) [4]. Due to the aforementioned factors, it is important that measures are taken to achieve Energy efficiency in wireless network to optimize the Energy consumed by the system.

Fifth Generation (5G) networks have a number of technologies that aid Energy efficient communication in wireless communication which, includes Millimeter Waves, LTE-U, Ultra Dense Network (UDN), Massive–MIMO, Device to device communication and spectrum sharing [5]. Device-to-Device (D2D) communication is a short range communication technology in 5G. It plays a critical role in enhancing the energy efficiency and spectral efficiency of the cellular networks. It boosts the reliability of the link between the users, through direct link formation and latency reduction [6]. D2D communication is promising for several benefits. The high link quality enables high data rates and low power consumption while also improving the spectral efficiency of the system [7]. As a result of these benefits, D2D communication has continued to gain extensive attention. The aim of D2D communication is to leverage on the physical proximity of communicating devices to extend the cellular coverage mostly in sparse environments. D2D communication supports various technologies such as Ultra-wideband (UWB), Near Field Communications (NFC), ZigBee, Bluetooth, WiFi Direct or LTE Direct [8].

Most of the research work carried out to improve Energy efficiency focuses on the Network operator side with little concern given to the Mobile device side [9]. Hence, the contribution of this work is to focus on Energy efficiency that's user centric by optimizing the transmit power of user devices in a D2D communication network through appropriate allocation of transmit power to achieve the target data rate of each Primary Receiver.

II. RELATED WORK

For ensuring coverage all the time and everywhere, the concept of spectrum sharing (SS) has been anticipated. It allows secondary users to access the unutilized/underutilized parts of the spectrum through different sharing strategies (underlay/overlay/mixed). It is a productive technology for simultaneous energy efficiency maximization and spectral efficiency management [10]. For example, [11] used power control strategies to investigate the cross-interfering spectrum sharing system. The aim was to maximize the achievable transmission rate of the secondary link over Rayleigh fading channels. The authors applied the Karush-Kuhn-Tucker (KKT) conditions, to design the optimal power allocation strategy. Battery of mobile terminals (MT) were

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prolonged in [9] by optimizing the transmission power of the Primary Transmitter (PT) in a Spectrum Sharing (SS) network, for improved Energy Efficiency by placing the Primary Receivers in different zones. The transmission power required by the PT for achieving the target rate of the demanded applications by PRs is computed, and the PT then accordingly regulates its transmitter power level, in each zone. The Secondary transmitters (ST), sharing the primary spectrum, simultaneously communicate with the secondary receivers (SRs). The remaining power levels of the STs are also determined, for their use as an Amplify and Forward relay, in case the target rates are not met over the PT →PR links.

Similarly, [12] developed a linear optimization accurate model to minimize the power consumption of an LTE cellular network while affording a minimum data rate for each mobile terminal. The optimization framework finds the solution for the users, power and bandwidth assignment problems, using a SINR interference model. An Exact Energy Consumption in a Cellular Network (ECCN) algorithm was developed to minimize the energy consumption in the network. For a given traffic, the solution of the Exact ECCN outputs the best set of active base stations to serve the users, the user assignment and the resource allocation, while guaranteeing each user with the minimum required data rate. Simulation of the Exact ECCN optimization model was implemented on IBM ILOG CPLEX Optimization Studio 12.6.0.0.

Therefore, to achieve a novel Best cooperative mechanism (BCM) for wireless energy harvesting and spectrum sharing in 5G networks, the authors in [13], proposed a technique where Data transfer and energy harvesting are finished in the designed timeslot mode. In the proposed BCM, secondary users (SUs) harvest energy from both ambient signals and primary user's (PU's) signals. In addition, there is a cooperation where SU's can act as relay for PUs to enhance PUs transmission abilities (throughput) and harvest energy from PU signals simultaneously. The proposed mechanism allows optimal time duration for data transfer within the timeslot. Also, to minimize power consumption, in [14] focus was on user association scheme to achieve traffic load balance of the whole system. The base station with low traffic load is switched into sleep mode. Under the constraints of both coverage and rate requirements of all users being guaranteed, an algorithm was proposed to offload Mobile Users in sleeping cell to neighbor active Base stations effectively. Energy efficiency is achieved in [15], by developing a joint power and radio resource allocation for D2D communication. Energy efficiency was also considered as an optimization objective since the devices are handheld equipment with limited battery capacity. To achieve Battery optimization of smartphones, [16] improvised a technique based on reduction in energy consumed by communication over the network. This was achieved by utilizing cooperative device-to-device communication. The proposed system allows users with higher battery level to carry traffic of users with lower battery level, thereby reducing the chances of user running out of battery early. The technique used is known as the Battery Deposit Service (BDS).

Also, [17] studied resource allocation for energy efficient device-to-device (D2D) communications in an overlay wireless cellular networks, where a D2D transmitter first harvests energy from a base station (BS) and then communicates with a D2D receiver. The resource allocation algorithm design is formulated as a non-convex optimization problem for the maximization of the energy efficiency of the D2D system. The proposed problem formulation takes into account the minimum required harvested energy, maximum duration of signal transmission, and minimum required system throughput. Exploiting fractional programming theory, the non-convex problem was transformed into a standard convex optimization problem. From [18], in order to increase the efficient communication distance between D2D pairs, a relay was utilized to breakdown the distant path into two shorter segments, forming a two-hop link. The geometric region where this relays exist are referred to as the Energy saving Zone. The stochastic distribution of the energy saving is introduced by relays inside this region. Using Monte-Carlo simulations, results suggest that a sufficient energy saving can be achieved when relay-assisted device-to-device communication. A new devices-to-device (Ds2D) communication paradigm is proposed in [19] to establish D2D communication over multiple radio interfaces between a sink and source devices which would in turn improve energy consumption and battery life of mobile devices involved in such emerging Device centric Applications. Ds2D makes use of one of the multi-homing D2D radio interface per source device. In addition, Ds2D communications incur lower transmission power per sourced device compared to the multi-homing D2D and traditional D2D approaches, based on the file split ratio among the different source devices as such increasing the device battery lifetime.

III. PROPOSED TECHNIQUE FOR ENERGY CONSUMPTION MINIMIZATION

Further improvement in the work of [9], would be carried out and the system model in this case would include a mobile Primary Transmitter as against the static Primary Transmitter used in the previous work and MATLAB will be used for simulation. The system configuration would involve a Mobile Primary Transmitter (PT) at an initial position forming D2D links with Primary Receivers (PRs) each placed in four different zones labelled Z1 to Z4 with three PRs each in any zone. The initial position of each zone from the PT are 5m, 10m, 15m and 20m for Z1 to Z4 respectively. The secondary system consists of Secondary Transmitter (ST)-Secondary Receiver(SR) pairs operating cooperatively in the Primary network with limited interference [16] and acts as an amplify and forward relay for the Primary Transmitter when at Threshold power.

The set of applications requested by any i^{th} PR(PR1, PR2 and PR3) in any n^{th} zone(Z1,Z2,Z3,Z4) is given as Ap (A_1,A_2,A_3) having target rates of R_p^1, R_p^2, R_p^3 respectively.

When the PT has insufficient power to complete a direct transmission to a PR as a result of a far distance, the transmission is relayed through an appropriate ST with sufficient power. However, due to the mobility of the PT, if a transmission is being relayed and the PT moves closer to the PR in consideration, the PT continues direct transmission if its available power is iterated and found sufficient.

This proposed model is a work in progress and the next stage is to subject the algorithm to simulation in order to obtain performance evaluation. The Mobility of the primary transmitter is expected to yield higher power saving when compared with the work of [9] as a system model would be developed to allow the mobile Primary transmitting device select the most suitable Secondary transmitting relay device or take back transmission from ST when closer to the Primary receiver.

To initialize this process the PT location from the various PRs is determined through Global Positioning System. The zonal division helps to determine the required power level in each zone.

The achievable data rate of the primary system in any n^{th} zone to a particular i^{th} PR for each demanded application (Ap) is computed as

$$R_p^n = Blog_2\ (1 + SNR_n^I) \quad (1)$$

Where B is Bandwidth in Hz

The SNR_n^I is computed as $P_T^{ti,n}\ \frac{|hPT,PRi,n|^2}{\sigma_0^2}$ [20] (2)

Where σ_0^2 is average power and hPT, PRi, n is channel coefficient between PT and i^{th} PR

The required transmission power for achieving the target rate R_p^n, for the requested application by i^{th} PR, in n^{th} zone, over the PT→ $PR_{i,n}$ link is given by

$$P_{req}(i,n) = \frac{\sigma_0^2}{|hPT,PRi,j|^2}\left(2^{R_{T/B}^{Ai}} - 1\right)\ [20] \quad (3)$$

Power is saved after each successive transmission that satisfies a demanded application and denoted as

$$\text{Psaved} = P_{max} - \text{Preq} \quad (4)$$

Depending on the level of Psaved (ST), appropriate ST is selected for relaying in accordance with PR application demands and corresponding data rate.

TABLE 1: DESCRIPTION OF DESIGN PARAMETERS

Parameter	Description
Primary Transmitter (PT)	This refers to the single Primary Transmitting User Equipment which is mobile and forms D2D links with the various Primary receivers.
Primary Receiver (PR)	This refers to the various Receiving user equipment that also forms D2D links with the single primary Transmitter.
Secondary Transmitter (ST)	These are secondary Transmitting user equipment's that form ST-SR pairs in the D2D network scenario, through cooperative spectrum sharing. The ST also serves as an amplify and forward relay for the PT.
Secondary Receiver (SR)	These are secondary receiving user equipment that form ST-SR pairs in the D2D Network.
Power Required (Preq)	This is the required power for transmission in other to achieve the required target rate.
Maximum Power (Pmax)	This is the maximum transmitter power obtained initially before the first transmission occurs.
Threshold Power (Pthreshold)	This is the threshold power level of the Transmitting device. At this level, no direct Transmission between the PT –PR pairs can occur, hence the need for transmission relay through the appropriate PT-ST pair.
Distance (d)	The distance between the PT and the various PRs forming D2D pairs
Channel Gain (G)	The channel gain between the Transmitting device and the Receiving device.
Secondary Transmitter power level (P_{ST})	This is the power level available at the Secondary transmitting device capable of relaying a PT transmission.
Power saved (Psaved)	This is the power saved in the transmitting device as a result of the optimization of the transmit power. Denoted as Psaved= Maximum Power – Required power
Requested Application (Ap)	This refers to the various application requested by the PRs

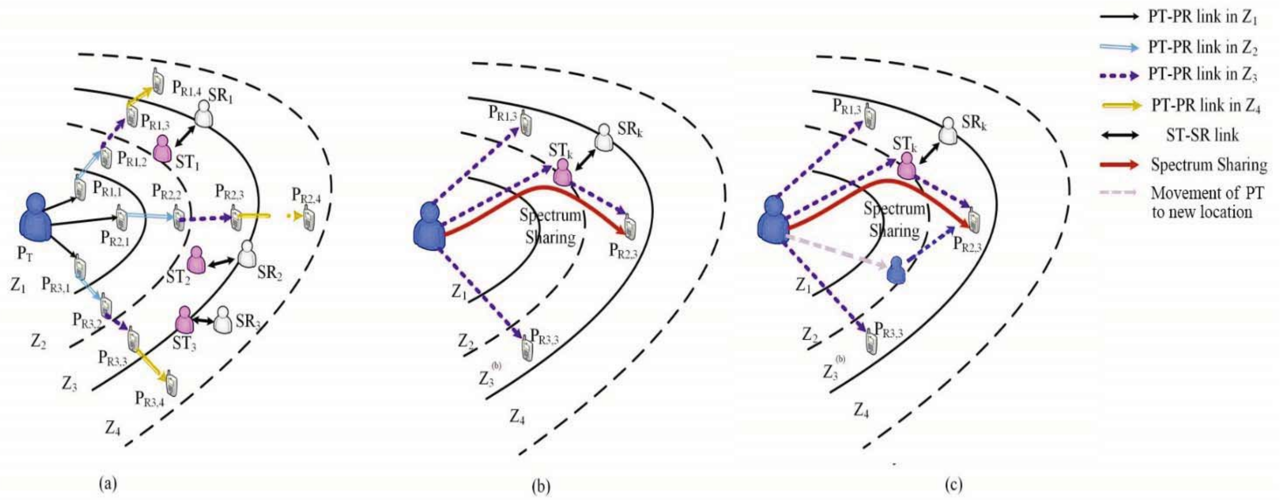

Fig. 1(a) system model (b) spectrum sharing in z3 with appropriate selection of ST (c) New Location of PT, closer to PR for direct transmission

IV. FLOWCHART OF PROPOSED TECHNIQUE FOR ENERGY CONSUMPTION MINIMIZATION

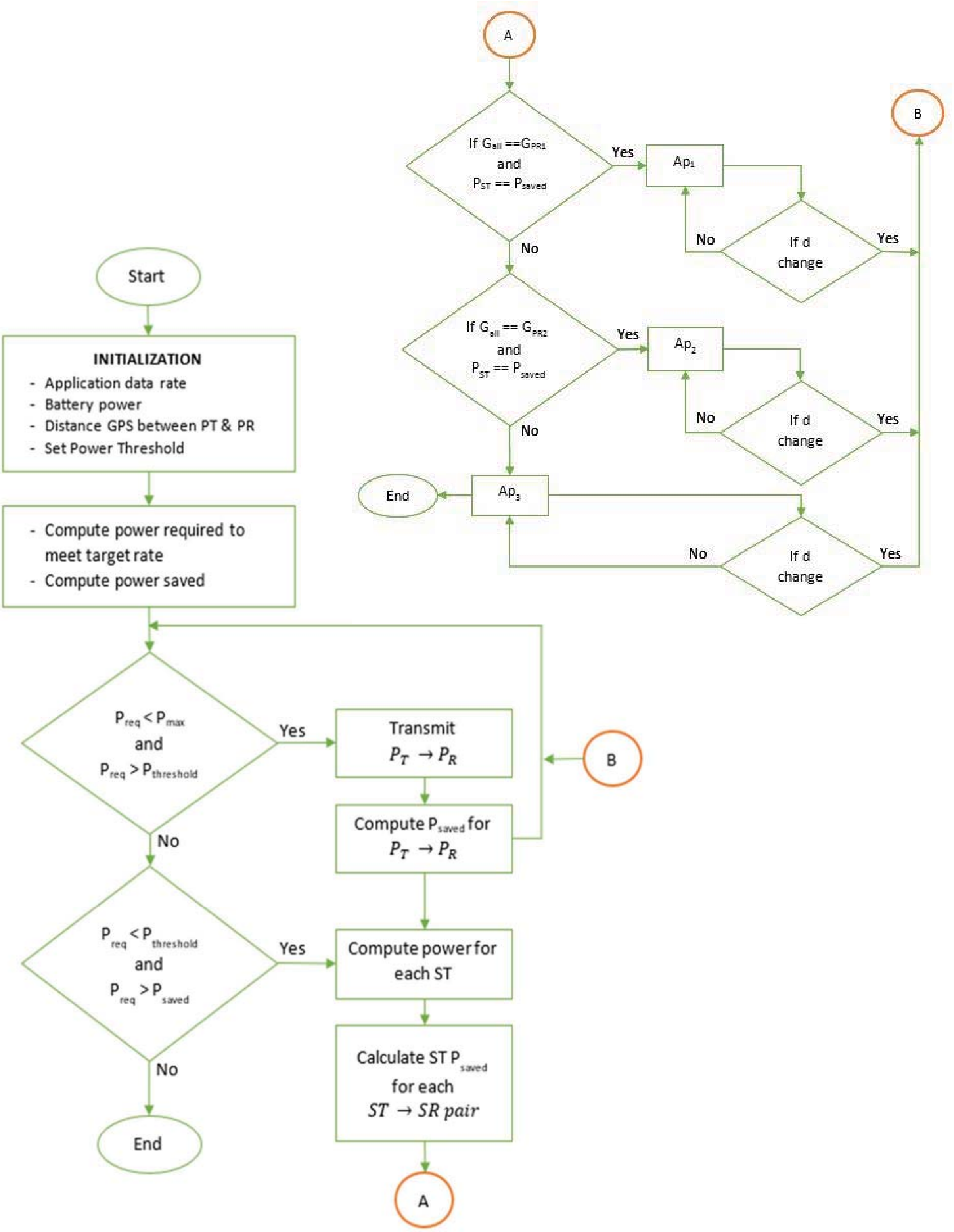

Fig. 2 Flowchart showing the step by step procedure for proposed algorithm

V. CONCLUSION

In this study, wireless mobile network Energy efficiency models are briefly described with emphasis on D2D communication. It can be observed that Mobile Users demand a range of multimedia services requiring low to high data rate and desired quality of experience everywhere and all the times. This high data demand, leads to more energy usage, which leads to a fast depletion of power level in mobile devices.

However, in 5G network, utilizing device-to-device plus spectrum sharing techniques, using the proposed algorithm in this work, power level requirement for communication would be minimized without compromising the quality of service, therefore making the entire system energy efficient which is a metric for green communication.

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