Hybrid Data Compression and Zonal-Based Green Algorithm: Towards User Battery Power Conservation in Device-To-Device Communication

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Received: 22.12.2023 **Revised**: 05.09.2024 **Accepted:** 06.09.2024 **Published:** 04.10.2024

Abstract:
Owing to the rapid increase in data demand, the need for power saving in mobile communication is very important. This study proposes a combination of a zone-based technique, also known as the Zonal Based GrEEn (ZBGrEEn) algorithm, with the Lempel Ziv Welch (LZW) data compression algorithm in order to produce significantly more energy-efficient device-to-device (D2D) communication network. The system is modeled as a device- to-device communication between one primary transmitter (PT) and many primary receivers (PRs) located in various zones around the PT. The ZBGrEEn algorithm ensures that power allocation is optimally performed to meet the target rate of each application needed by PRs. Both the transmission time and transmission power computed in the ZBGrEEn algorithm are minimized due to the reduced data size achieved by applying the LZW algorithm on the data. Simulation results show an increase in battery lifetime of mobile devices from 46.28% (achieved when ZBGrEEn algorithm is used alone) to 51% when ZBGrEEn is combined with LZW algorithm. It can be noted that implementing both ZBGreen and LZW algorithms lead to improved power allocation and energy efficiency. These improvements could be further enhanced by investigating the effect of other compression algorithm on the combined ZBGreen and LZW algorithms presented in this paper.

Keywords: Data Compression, Device-To-Device Communication, Zonal Based GrEEn.

1. Introduction

OVER the years, the telecommunications industry has evolved to meet rising user demands [1]. During the past decade, there has been an increase in demand for wireless communication services, which now include video streaming, data applications, and telephony services [2]. This development has been accompanied by the widespread application of wireless access networks [3]. Since the emergence of smartphones, there has been an increase in demand for wireless data transmission. The global mobile data traffic increased by 71 percent in 2017, reaching 11.5 exabytes per month, up from 6.7 exabytes per month at the end of 2016. This amount was expected to increase sevenfold between 2017 and 2022, reaching 77 exabytes per month by 2022. Furthermore, it is projected that in 2022, 79% of mobile data traffic will be video, and there will be approximately 12.3 billion mobile devices, which surpasses the estimated global population for the year 2022.

A 1000-fold increase in capacity is predicted for the emerging 5G wireless network as compared to the currently available network [4]. This development is projected to have a negative impact on energy consumption. This

increase in energy consumption brings about an increase in the cost of operation. Also, it will lead to environmental challenges such as an increase in greenhouse gases emission [5]. These effects would include environmental hazards, as the telecommunication industry is responsible for 2% of the total CO2 in the atmosphere worldwide presently and is projected to increase by 4% by 2020. These growing emissions emanate from mobile devices, radio access networks, and the use of fossil fuels to power base stations [6, 7]. From a financial point of view, a substantial number of yearly operating expenses (OPEX) for a network provider is increased. For cellular networks not connected to the power grid, the expenditure on energy reaches up to 50% of the OPEX [8, 9]. Several technologies aid energy-efficient communication according to Wu et al. [4] who elaborates on millimeter Waves. Ultra-Dense Network (UDN) is another new technology that is gotten by extensively installing several types of base stations in hotspot locations. This may be considered a large version of heterogeneous networks.

Following the growing data rate, improving energy consumption efficiency in mobile Device-to-Device communication must be done. This is posing a serious challenge to researchers. However, compression techniques have shown significant power savings when utilized [10]. In addition to the carbon emissions into the environment and cost factor, other reasons for moving towards green communication include the increasing health concerns and also the battery life of devices. Although the telecommunication industry is growing at a very fast rate, battery technology is growing at a comparatively slower rate. The growth in battery capacity is about 1.5x per decade. With the drastic increase in multimedia communication, the battery of smartphones has become a major challenge to the industry. This calls for the user terminals to be efficient in energy consumption. Thus, the exponential increase in the number of users and the number of devices has sparked a surge in interest as regards the topic of low-power, energy-efficient communication.

A major reason for the lack of efficient use of energy from the above-stated problems according to [11] can be due to lack of optimal resource allocation in terms of efficient utilization of resources with reference to time, frequency, and space, lack of optimal network planning, non-utilization of renewable energy sources, as well as transmission of high data size. There is a lack of attention on the mobile device side of the equation when it comes to improving energy efficiency. Hence, the motivation for this research is to focus on the power saving of mobile devices in other to establish a balance in the entire wireless network's energy efficiency. In this regard, this study aims to improve mobile devices' battery lifetime by compressing the Data size using Lempel Ziv welch compression technique and overall Energy efficiency of the Device-to-Device communication network. Therefore, the objectives of the study are to design and analyze a model for collaborative device-to-device communication, use Lempel Ziv Welch compression technique to reduce transmitted data size and transmit power, simulate the proposed model using Matlab, and evaluate the proposed model's performance with reference to energy efficiency and improved mobile battery lifetime.

This remaining part of this work is organized as follows: section 2 gave an overview of D2D communication and reviewed related works. Section 3 presents the approach used in this study; section 4 discusses the results while section 5 concludes the paper.

2. LITERATURE REVIEW

Device-to-device communication (D2D) is communication between devices within a close range. It can operate on the licensed and unlicensed frequency spectrum without passing through the core network. This technology makes it possible to achieve a higher throughput, lower latency, lower transmission power, higher data rate, higher energy efficiency as well as spectral efficiency [12]. This technology (D2D communication) aims to take advantage of the proximity between communicating devices to improve coverage.

D2D communication will be able to provide a variety of services to end-users, such as public safety communication subject to infrastructure damage and proximity awareness. [13], 2018). D2D communication can achieve four types of gains as follows:

- Proximity gain: Using a D2D link, close-range communication allows for fast bit rates, low delays, and low power consumption.
- Hop gain: When interacting via a base station, D2D transmission requires only a single link (one hop) instead of making use of uplink and downlink (two hops) resources.
- Reuse gain: D2D and cellular links can share the same radio resources at the same time.
- Pairing gain: user equipment (UE) can interface with the BS in cellular mode or directly in D2D mode, allowing for more flexible communication.

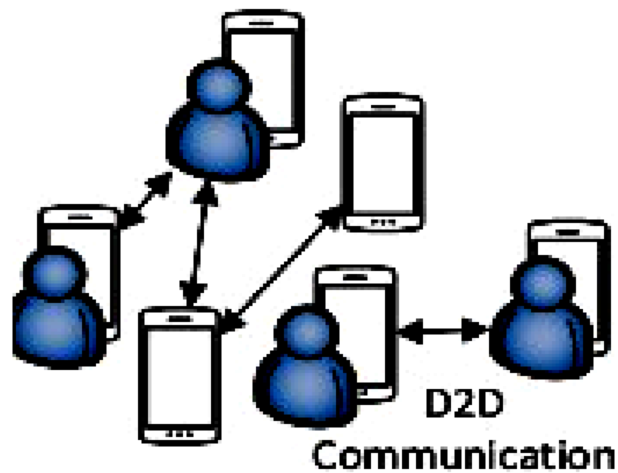

Figure 1: Standalone D2D communication scenario [14]

2.1 Achieving Energy Efficiency

One of the techniques for improving energy efficiency is spectrum sharing. Cellular networks have a dedicated licensed spectrum available for operation. Also, an unlicensed spectrum and various shared licensed spectrums are available for wireless communication. The radio spectrum is facing severe crowding, giving rise to the need for a dynamic spectrum allocation. Device-to-device communication is another technology that can achieve energy conservation in mobile wireless networks. [15] described a technology that gives an autonomous-intelligent-mechanism that results in an energy and spectrum efficient systems as it aids in facilitating peer-to-peer networks.

To ensure that the 5G network is both energy and spectrum-efficient, mobile terminals (MT) are considered [16]. The authors employed Primary Transmitter (PT) transmission power optimization in a Spectrum Sharing (SS) network to prolong the battery life of the MT by situating the Primary Receivers in distinct zones. It is true that a powerful battery is available at the MTs. However, the capacity to bear multiple applications simultaneously, without having to recharge the handset is restricted [17]. The differentiation of zones is made on the foundation of the Primary transmitter → Primary receiver (PT→PR) distance. The maximum distance of transmission for a D2D link is assumed to be 20m, which is also the assumed maximum PT→PR link distance and corresponds to the outermost zone [16]. The PT calculates the amount of power it needs to broadcast in order to meet the requested application rates from PRs, and then adjusts its transmitter power level proportionally in each zone. After serving a PR in a given zone, the PT iteratively serves the successive PRs in the various zones with the power that is left. Secondary transmitters (STs) and receivers (SRs) interact concurrently across the principal spectrum shared by the STs, and consume an equal amount of power in supporting the demanded applications over the ST →SR links. In addition, the remaining power levels of the STs are computed for their usage as an Amplifier and forward Relay in the event that the goal rates over the PT-PR connections are not fulfilled. Numerical results reveal that the efficiency of the proposed technique is confirmed and advantageous to the primary transmitter in terms of improved battery life. This brought about 46.28% in the battery lifetime enhancement.

The authors of [18] considered a multiuser mobile-edge computing (MEC) system with energy and latency restrictions, hence they introduced a data compression technique. The offloaded data is first compressed to reduce its size before transmission occurs. Simulation shows that combining data compression with optimized computation offloading and resource allocation results in significant energy savings. Also, [19] acknowledged that energy saving in wireless devices has been a challenge, therefore, they developed a Lempel Ziv Welch-based data compression scheme to tackle this challenge. In [10], the authors tried to save power on mobile devices by compressing the original data size before transmitting.

2.2 Compression Technique for Energy Efficiency in Mobile Communication

Various compression techniques for mobile communication were investigated and Lempel Ziv Welch Algorithm was discovered to be a lossless compression technique with the best compression ratio. As a result of the forecast from [20] stating that video files would be the most requested data in 2022, it is important to devise a fast, efficient, and energy-saving means of transmitting such large files. Hence, the study in [21] is useful as the authors focused on Compressing video files using Lempel Ziv Welch (LZW) technique. Comparing LZW compression algorithm with Huffman algorithm, it was observed that LZW algorithm was more efficient and simpler with faster execution.

From [22], it was stated that one of the most severe challenges experienced in IoT is the amount of power used during data transmission. To tackle the above challenge, they introduced Lempel Ziv welch compression technique prior to transmission of data. The technique is combined with Particle swarm optimization and deep neural network-based prediction model to achieve a compressive technique that is energy efficient with predictive model for IoT-based medical data collection and transmission. The combined LZW-PSO-DNN algorithm was investigated and found to achieve 98.4% accuracy in a compressed state. Analysis and performance evaluation of different lossless compression techniques such as run-length, LZW, Huffman, and Delta encoding were carried out by Gopinath and Ravisankar (2020) results show that Lempel Ziv Welch compression method shows better performance with a 4:1 compression ratio, and space-saving. Also, [23] carried out a comparative study of various lossless compression techniques. LZW was observed to be the fastest since it could carry out encoding in a single pass as compared to Huffman coding which required double passes hence leading to a slow process.

The compression ratio reveals the compression percentage made against the original file. It is the relative reduction in the size of the data represented by the compression algorithm. It is derived from the ratio of compressed file size to the uncompressed file size as shown in (1) [24]

$$Compression\ Ration = \frac{Compressed\ Data\ Size}{Uncompressed\ Data\ Size} \times 100\% \quad (1)$$

The greater the compression ratio, the lesser the resulting compression file, and ultimately, the better the compression result [25]. Also, studies from [21], indicate that the percentage compression of a video file is 24.54%

3. METHODOLOGY

After thorough research and feasibility study of the system was conducted, the steps in Figure 2 were taken to achieve the objectives while Table 2 defines the parameters used.

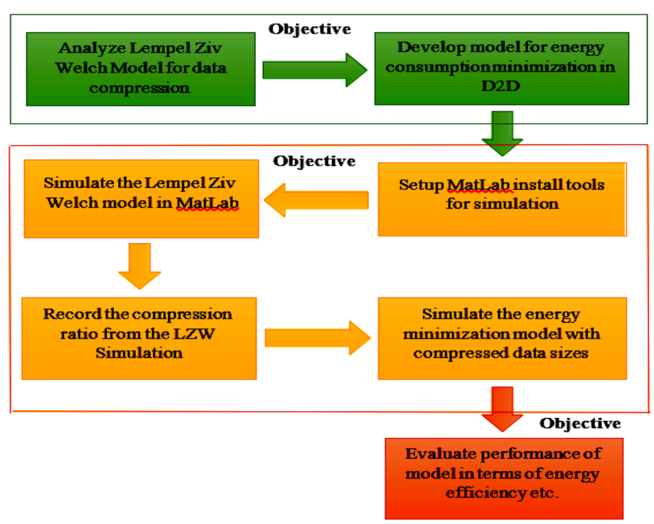

Figure 2: Research procedure block diagram

3.1 Technique for Energy Consumption Minimization

The work of [16] would be improved further, and the system model in this scenario would comprise a single PT communicating a compressed form of the original application data file size to its target PR. The system model was simulated using MATLAB. The goal is to minimize energy consumption by lowering the transmission time as a result of a compressed data size for transmission.

Table 1: Parameters of the design

Parameter	Description	Values
P_c	Circuit power consumption	100mW
$P_T$max	Primary transmitter maximum Power	23dBm
Pthreshold	Threshold power	70mW
Dmax	Maximum Distance	20m
Ap	Requested Application	Video(A1): 100MB Voice(A2): 50MB Text(A3): 200KB
R_T^m	Maximum achievable data rate	13.15Mbps
$E_{battery}^T$	Battery Energy consumption	7.45Wh
$I_{battery}^{capacity}$	Battery capacity	1960mAh
Parameter	**Description**	**Values**
P_c	Circuit power consumption	100mW
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R_T^m	Maximum achievable data rate	13.15Mbps

MatLab software was used for the simulation of this work and the procedure is shown in the flowchart in Figure 3.

The system setup have a PT at an initial position establishing D2D linkages with PRs positioned in four distinct zones named Z1 to Z4, each with three PRs. Each zone's distance from the PT is 5m, 10m, 15m, and 20m for Z1 to Z4, respectively. Ap is the set of applications requested by any ith PR1, PR2, and PR3 in any nth zone (Z1-Z4), with R1, R2, and R3 target rates respectively.

Application A1 which is a Video file has an original file size of 100MB, Application A2 which is a Voice file has an original file size of 50MB, and Application A3 which is a text file has an original file size of 200KB [26].

At initialization, the system computes the PT optimal power to transmit at the Achievable data rate RAi . Once this is achieved, the various application data files are compressed using Lempel Ziv welch compression technique. A threshold power, Pthreshold, of the mobile device (PT) is set to stop the PT from transmitting once it deduced that its power level will drop to the threshold value if transmission occurs. This is to ensure optimal use of PT battery power.

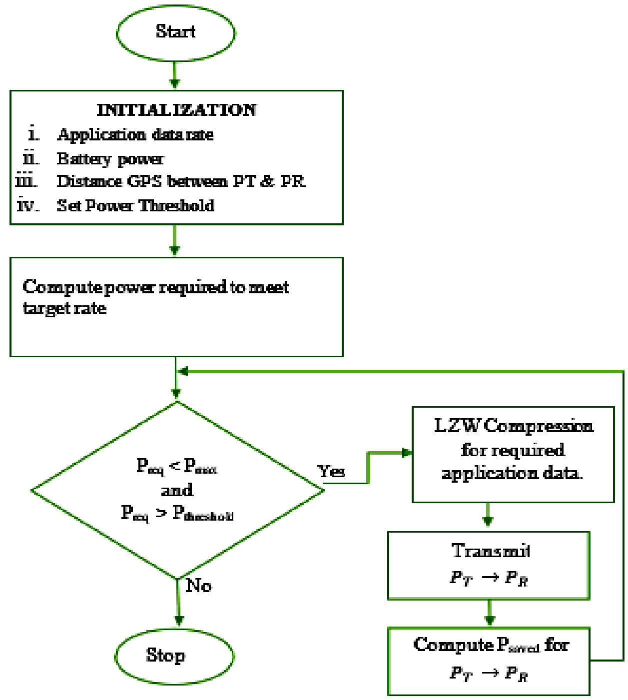


Figure 3: Flowchart of battery power conservation using ZBGreen algorithm and LZW compression technique

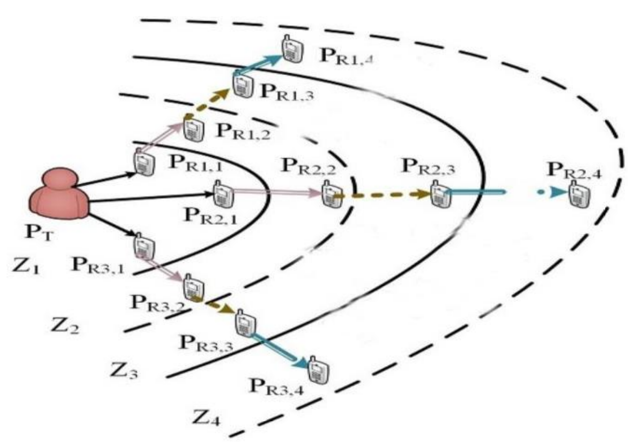


Figure 4: System model

The PT completes a transmission in zone 1 before transmitting to zone 2 until it gets to Zone 4. For each Zone, A1 is transmitted to PR1, A2 is transmitted to PR2, and A3 is transmitted to PR3 with priority in transmission given to A1 before A2 and finally A3.

Through the Global Positioning System (GPS), the PT's position from the PRs is calculated. For each zone, the zonal division helps establish the appropriate amount of energy.

4. RESULTS/FINDINGS

Making use of optimal power for transmission using the maximum target rate, as shown in the Matlab simulation of Figure 5, less power is consumed than using maximum power for transmission to minimize battery power consumption.

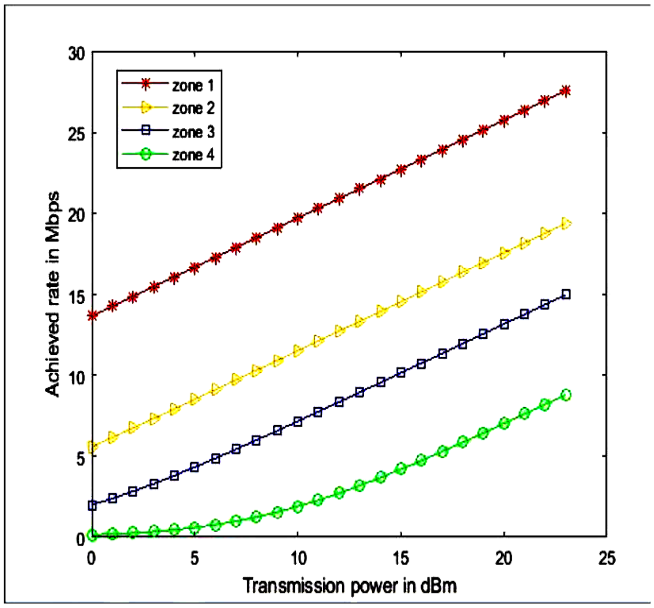


Figure 5: Achieved data rate using optimal transmit power

According to Table 2, the energy efficiency is calculated, using optimal power for transmission and the maximum achievable rate as described in [27] where the maximum data rate for each zone is given as 13.15Mbps and circuit power is assumed to be 0.1W together with the optimal power required to transmit each application in a particular zone. The varying values for energy efficiency are depicted depending on the cumulative power requirement in a particular zone.

4.1 Compressed Data Size Using LZW Compression Ratio

Using equation 2, LZW compression ratio, a Video file is compressed by 24.54%, a Voice file is compressed by 36% and a text file is compressed by 56% as shown in Table 3.

$$E^{j}_{consumed} = E^{T}_{battery} T^{j}_{i,n} \quad (2)$$

4.2 Transmission Time using Original Data Size and LZW Compressed Data Size

Energy consumed during data compression is considered by [28] where the transmission time for a 100Kb file is 0.005seconds. Hence, Table 3 shows the amount of time it would take to transmit each file for compression. This will aid in accessing the viability of using the compression technique considering the total energy for compression. The time to transmit the Original Data size in [27] and the LZW compressed data size as depicted in Table 4 is calculated and compared. Considering the packets of file size (application) demanded in bits per packet, the maximum target rate is 13.15Mbps.
Also, energy consumed during the compression of data is also considered by [28] where the transmission time for a 100Kb file is 0.005seconds. Numerical results show that the transmission time for the original data in each zone is higher compared to the time required to transmit the compressed data as shown in Table 5.

From Figure 6, it can be observed that, the transmission time is lower when the compressed data size is transmitted when compared with the transmission time of the original data size

Table 2: Energy efficiency using optimal power for transmission and maximum achievable data rate.

Zone	Data rate(Mbps)	Transmission power for A1(W)	Transmission power for A2(W)	Transmission power for A3(W)	Circuit power(W)	Energy efficiency (Mb/J)
Zone 1	13.15	0.001	0.001	0.001	0.1	127.6
Zone 2	13.15	0.019	0.002	0.012	0.1	93.5
Zone 3	13.15	0.1	0	0.01	0.1	62.6
Zone 4	13.15	0	0	0.005	0.1	125.2

Table 3: Compressed file size using LZW compression ratio

Type of file	Compression ratio	Compressed file Size	Original file size
Video File A1	24.54%	24.54MB	100MB
Voice File A2	36%	18MB	50MB
Text File A3	56%	112KB	200KB

Table 4: Time to process compression in each zone for each demanded application.

Time(s)

	Zone 1	Zone 2	Zone 3	Zone 4
A1 (100MB)	5	5	5	0
A2 (50MB)	2.5	2.5	0	2.5
A3 (200KB)	0.01	0.01	0.01	0

Table 5: Comparison of Transmission time (T_{tx}) for each demanded application at different zones for original and compressed data

	Zone 1		Zone 2		Zone 3		Zone 4	
	T_{tx} of origina l data (s)	T_{tx} of compres sed data (s)	T_{tx} of original data (s)	T_{tx} of compres sed data (s)	T_{tx} of original data (s)	T_{tx} of compres sed data (s)	T_{tx} of original data (s)	T_{tx} of compres sed data (s)
A1	60.8	14.93	60.8	14.93	60.8	14.93	0	0
A2	30.4	10.95	30.4	10.95	0	0	30.4	10.95
A3	0.12	0.068	0.12	0.068	0.12	0.068	0	0

Table 6: Energy consumed in Wh using transmission time for original data size (OD)

	Battery Energy consumption(Wh)	Transmission time (s)	Energy consumed(Wh)
Zone 1	7.45	91.32	0.18
Zone 2	7.45	91.32	0.18
Zone 3	7.45	60.92	0.13
Zone 4	7.45	30.4	0.06

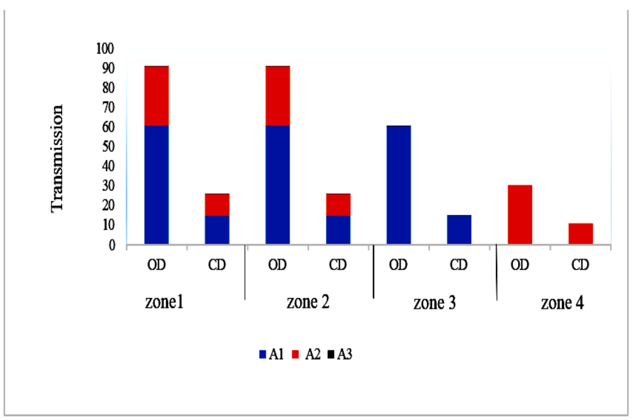


Figure 6: Graph of Transmission time against original data (OD) size and compressed data (CD) size

3 Energy Consumed for Processing Compression, Transmitting using Original Data Size, and Transmitting using Compressed Data Size

In order to determine if the packet data has an impact on the energy used up during transmission by the Primary Transmitter, the time, for transmitting each demanded application in a particular zone and the primary transmitter battery usage, are considered based on energy consumption.

Tables 6, 7, and 8 show the energy consumed in processing compression, transmitting the original and compressed data, respectively. From Table 6-8, the Energy consumed in Wh is calculated using (2). The battery energy consumption (ET) is given as 7.45Wh in [27] and the values of transmission time are obtained from the summation of the transmission time for each application in a particular zone in Table 3 using equation (3). From Figure 7, comparing the energy consumed when the original data size is transmitted versus energy consumed when the compressed data size is transmitted, it can be observed that the energy consumed for each zone using compressed data size is lesser than the energy consumed using the original data size.

$$T_{i,n} = \sum - \frac{PnBn}{R_T^{Ai}} \quad (3)$$

The value for energy consumed in Wh is gotten from Table 6, the value for battery capacity is given as 1960mAh by [27] while the battery current for each zone is obtained from equation (4).

$$I_{T,n}^{j} = \sqrt{\frac{E^{j}_{consumed\ (i,j)} \times I^{2}_{battery\ capacity}}{E^{T}_{battery}}} \qquad (4)$$

Table 7: Energy consumed for processing compression

	Battery Energy consumption (Wh)	Transmission time (s)	Energy consumed(Wh)
Zone 1	7.45	7.51	0.02
Zone 2	7.45	7.51	0.02
Zone 3	7.45	5.01	0.01
Zone 4	7.45	2.5	0.005

Table 8: Energy consumed in Wh using transmission time for Compressed data size (CD)

	Battery Energy consumption (Wh)	Transmission time (S)	Energy consumed(Wh)	Total Energy consumed from processing and transmission(Wh)
Zone 1	7.45	25.95	0.05	0.07
Zone 2	7.45	25.95	0.05	0.07
Zone 3	7.45	14.99	0.03	0.04
Zone 4	7.45	10.95	0.02	0.025

Table 9: Battery lifetime in hours for Zbgreen Algorithm

	Energy consumed (Wh)	Battery capacity (mAh)	Battery current drawn for zonewise transmission(mAh)	Battery life(h)
Zone 1	0.18	1960	0.30	18.57
Zone 2	0.18	1960	0.30	18.57
Zone 3	0.13	1960	0.25	19.48
Zone 4	0.06	1960	0.18	21.62

Table 10: Battery lifetime in hours for compressed Data size

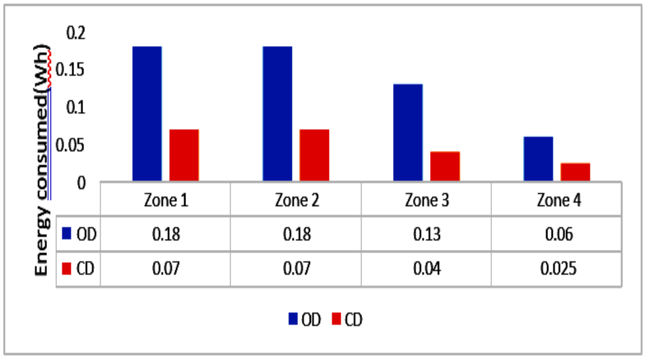
	Energy consumed (Wh)	Battery capacity (mAh)	Battery current drawn for zone-wise transmission(mAh)	Battery lifetime(h)
Zone 1	0.07	1960	0.19	21.22
Zone 2	0.07	1960	0.19	21.22
Zone 3	0.04	1960	0.14	23.60
Zone 4	0.03	1960	0.12	27.70

4.4 Battery Lifetime of Primary Transmitter

As a result of reduced energy consumption in each zone using the compressed data size, the impact on the battery lifetime of the primary transmitter is also calculated using (2)

$$B_{lifetime} = \frac{I_{battery}^{capacity}}{I_{PT}^{j}} \times 0.7 \qquad (5)$$

Where $Icapacity$ is the primary transmitter battery capacity and Ij is the primary transmitter $battery\ \ PT$ battery current and 0.7 represents external factors that can affect the battery life of mobile devices [16].
The battery life in hours is calculated for Zbgreen algorithm in Table 9 using equation (5) while that of the compressed data is given in Table 10.



4.5 Prolonged Battery Lifetime of Primary Transmitter

From Figure 8, which is a plot of the battery life in hours obtained from Tables 8 and 9 against the different zones where various PRs are located. As stated in [26], every user in the network has an initial battery lifetime of 14 hours which is fully charged. It can be observed that the battery life is further prolonged when the transmission is done with values obtained using the compressed data size as compared to using values from the original data size of Zbgreen algorithm. The original data size of Zbgreen Algorithm has a battery lifetime enhancement of approximately 46.28% which is depicted with the blue line in Figure 8, while the compressed data size algorithm led to a further increase in battery lifetime by approximately 51% which is depicted with the orange line.

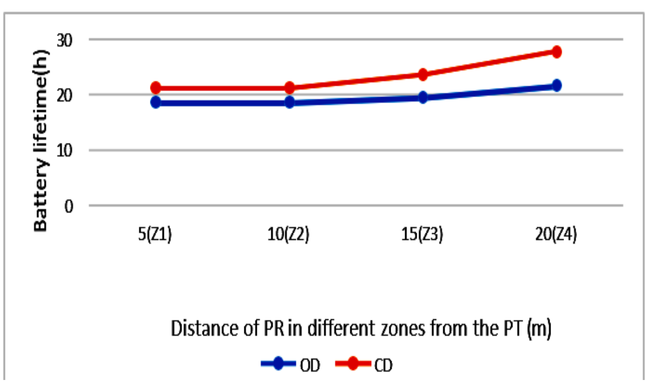


Figure 8: Battery lifetime of the PT in hours when original Data size is transmitted compared to transmitting the compressed data size

5. CONCLUSION

In conclusion, smartphones are relevant in enabling device-to-device communication. Mobile users expect a wide variety of multimedia services that require low to high data rates and quality experience everywhere and at any time. This increased demand for data increases energy consumption, which results in a rapid depletion of mobile device power. On the other hand, in a 5G wireless network, as considered in this work, using the achievable rate, optimal transmit power, and a compressed data size in Device-Device communication, an algorithm combining two energy-efficient techniques has been developed. The zonal-based green (Zbgreen) algorithm which focuses on the optimal zone-wise transmission of demanded applications with different file sizes is combined with Lempel Ziv welch compression technique to further reduce the original Zonal based green algorithm file size before transmitting to the intended Receiver. The performance of the system using only zonal-based Green Algorithm versus its combination with Lempel Ziv welch compression technique is compared and evaluated. While Zbgreen algorithm alone gave 46.28% battery life enhancement, the combined algorithm gave 51% without sacrificing service quality. From the outcome of this study, it is suggested that further studies can be done to investigate the effect of other compression techniques to get a higher percentage of power-saving on mobile devices. Also, in addition to data compression, the effect of energy harvesting combined with the algorithm in this paper can be investigated for additional power savings.

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