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An Energy-Efficient priority Scheduling Technique for Disaster Response Cellular Networks

D. Srinivasa Rao[1], Ch.Rajasekhar[2], GBSR Naidu[3]
[1,3]Dept. of ECE, GMR Institute of Technology, Rajam, Andhra Pradesh. srinivasarao.d@gmrit.edu.in
[2]Dept. of EECE, GITAM Institute of Technology, GITAM (Deemed to be University), Visakhapatnam. rchukka@gitam.edu

ABSTRACT

During the natural or man-made disasters, telecommunication plays a major role to provide communication among population, government authorities, and to carry rescue operations in the affected areas. However, due to the lack of power and damaged infrastructure it may take several days to resume the entire communication network. In this scenario, it is highly needed to have an effective and timely response to establish persistent and reliable communication. Device-to - Device (D2D) Communication is among the recent advancements to achieve greater device performance by benefiting from short distances, direct communications and the variety of users. The main objective of this work is to provide substitute access to mobile networks if they are affected partially or completely by natural disasters. So, the concept of radio frequency based energy harvesting is employed. Energy harvest will power communication devices and environmental networks. A priority-based energy efficient scheduling (EES) technique is proposed to select the clusters that have less effective signal strength. Further, an optimal communication route is discussed that reduces the loss of connectivity and assists the connection from the serviceable area to inoperable zone. The suggested scheme dramatically saves energy for both cluster heads and user equipment (UE) in crucial circumstances like disasters.

Key words: Energy, cellular, disaster, scheduling, clustering

1. INTRODUCTION

Disasters are a natural or human phenomenon which can impact the lives, properties, livelihoods or industries of people, communities and the environment sometimes result in severe effects [1]. It is a dramatic, catastrophic event which gravely interrupts the working of the society or group and causes a loss of life, rationality and the economy. Disaster management can be described as the variety of activities aimed at managing disasters and emergencies to provide a mechanism for supporting people at risk [2]. For the recovery of the communications and to survive the victim's lives, the disaster management is proposed by different technologies for faster and better communications. And situations like earth quakes, tsunamis, storms need power supply, low power operating devices and systems.

There is another way that is by using batteries but it consumes more power compared to the other network. To reduce the effects of public security crises, effective communication response through situational awareness and crisis management, including emergency surveillance, reporting and relief, must be implemented rapidly.

Following the disaster, victims of disasters could not use their communication tools, such as mobile phones, tablets or laptop computers, to inform the friends and family of their security. The development of new technologies such as content delivery and messaging has created new services for Device-to-Device (D2D) communications in mobile networks [3]. All communications in cellular networks must pass through the Base Station (BS), even though all network nodes are in a wide range. D2D links enables a feature that the user equipment will directly contact to each other without using the base station. D2D communication may enhance performance, energy savings, delay and fairness [4]. It has also applied to allow for multicast controllers in mobile networks.

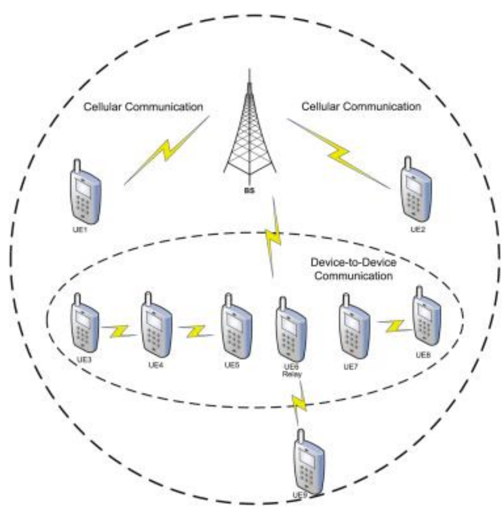

Figure 1: Cellular and D2D Communication

In Figure 1, we can see the difference between D2D communication and Cellular Communication. The number of devices will form the clusters and the cluster heads communicate to each other. D2D communications are two types. They are inband and outband. The inband and outband again are of two types. They are underlay and overlay in the Inband; autonomous and controlled in the outband. In coordinating communication across two different bands, outband D2D communication faces a few challenges.

1.1 Inband D2D

The Inband principle says that for D2D and cellular connections, the cellular spectrum can be used. Typically the high control over cellular spectrum is the reason for choosing inband connectivity. Many studies found abrupt behavior in the unlicensed spectrum, which brings quality of service (QoS) restrictions [5]. Inband connectivity can further be classified into groups of underlay and overlay. Cellular and D2D communications share the same radio infrastructure in underlay communication. In comparison, D2D connections are equipped with dedicated cellular services in overlay communication. Inband D2D can enhance cellular network spectrum efficiency by reusing spectral resources or assigning different cellular resources.

1.2 Outband D2D

Outband D2D utilizes non-licensed spectrum that makes the problem of interference between D2D and mobile users insignificant. Outband D2D, however, may be affected by the chaotic aspect of the unlicensed spectrum. It must be remembered that only two smart networks such as LTE and Wi-Fi can use D2D outband and therefore users can have both D2D and cellular network systems [6]. Figure 2 demonstrates the scheme of cellular scenarios for overlay inband, underlay inband, and outband D2D.

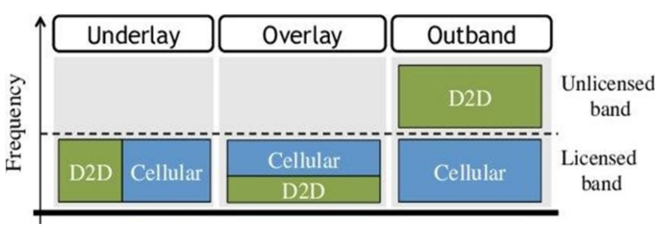

Figure 2: Types of D2D underlay, overlay and outband

The objective of this work is to maximize the overall energy efficiency of the network while satisfying the rate and power constraints for all users. For several users, the network is shown to be robust and scalable. It helps reduce the effect of resource and service limitations to address major issues such as power failure, traffic congestion and network efficiency during disasters. The combination of energy harvesting, scheduling and routing enables the users in disaster zone stay connected to the network. The proposed energy-efficient scheduling (EES) approach showed that both UE nodes and cluster heads can save significant energy in emergency conditions. However, our proposed approach adds a new component to the network survival process. The rest of the paper is organized accordingly. Section 2 provides a brief literature discussion. The system model description is given in Section 3. Section 4 describes the findings obtained. Section 5 finally concludes the paper.

2. RELATED WORK

The author in [7] proposed a D2D energy efficient communications for disaster conditions. The typical direct communication between the user equipment and base station is described. This model is used for SMS messaging. The compare of the energy consumption is performed with previous works. Here, the relation between the transmit radio frequency of the user equipment and its energy consumption in sending SMS is discussed.

In [8] the author suggested a smartphone technique relay for the realization of a multihop equipment for mobile communications relevant to several different wireless technology and addressed some open challenges. Generally the first prototype of relay by system is used to send the messages using only user's mobile devices. In the field experiments success, they got to know that the advancement in implementing user-driven networking is controlled by communication devices. Routing is a primary technology in multihop wireless communications. To enhance the coverage area using multihop D2D communication system, in [9] Interconnectivity is used among networking technologies like satellite network systems, unmanned vehicles and movable deployable resource units. If a connection with other networks is established, sending message to far users is possible. Gateway should not restricted to bridge networks regarding efficient utilization of network resources. The author in [10] proposed the dubbed relay by smartphone. The main advantage is that users can relay messages from other mobile devices, including smartphones, tablets and personal computers. In [11] Energy harvesting using amplify and forward MIMO relay system is discussed. The nodes i.e., source node and relay node employ the orthogonal space time block codes (OSTBC) for the transmission of data. The author has derived an optimal source and relay precord for meeting various constraints between the transmission capacity and the data rate defined by the rate area boundary. In [12] the author suggested the wireless information and power transfer scheme to enable the recovery of the communication network. Wireless power transfer methods is divided mainly into two categories namely electromagnetic induction and electromagnetic radiation. The methods which increases the power transfer efficiency and reduces the human exposure to the radiation were discussed. A hybrid inductive power transfer architecture with power relay is introduced. In [13], the author discussed an Energy-efficient scheme for wireless networks use renewable energy in the region of disasters. It describes the optimization of data traffic throughput and energy consumption with changing traffic demands. To achieve this objective, it need wireless mesh networks, base station with renewable energy, time and resource allocation system. An off-line scheme that considers the energy-harvesting profile to achieve an energy efficient result is addressed. An online scheme is discussed, which changes on the basis of real-time information and outcome of the off-line scheme.

For well energy consumption and management, cellular networks discusses about increase of power consumption and methods to reduce that power consumption. In [14], a new algorithm is introduced to reduce the energy consumption using Micro and Macro base stations. The suggestion of this algorithm is that heterogeneous LTE network power consumption can be reduced using micro and macro base stations. It measures the energy consumption of various cell patterns and selects the lowest energy consuming scenario. Bringing Movable and Deployable Resource Unit (MDRU) Networks to Disaster Areas, says that expected network configuration should be easily done. Higher number of users should be provided with services while covering a large area. The MDRU architecture enables ICT infrastructure to be restored quickly in disaster-related areas by deploying mobile resources. It also fulfills the necessary functions for the provision of ICT services like telephony and information exchange. A Green D2D communication with harvesting energy in cellular networks is discussed in [15]. Nevertheless, because the UE must use its own power to transfer data of others, transmitting D2D may be unfair. In order to overcome this problem, the D2D communication was considered where UE collects RF energy from the base station. In [16], the author discussed a resource aware scheduling strategy for mobile networks with cloud platform.

3. SYSTEM MODEL

The proximity of mobile communication with D2D has unique topographies that are useful in emergency and disaster circumstances. While the base station with ad hoc method may provide reliable communication, the wireless link between users may easily formed with enhanced possibilities.

3.1 Energy Harvesting

The disaster management architecture is usually considered as public safety scenario. It primarily contains source, relay and destination nodes. The source is generally a base station which has some fixed energy supply can transmit the information which it contains to a required destination node in the outage coverage area. There is a barrier between the source and destination node which is the relay node. The source is therefore unable to transmit its signals directly to the destination; hence, it asks for a relay node to assist its transmission of information through device to the vicinity of system communication. But the relay needs to harvest energy before being able to help other nodes, due to a lack of energy supply. Figure 3 depicts the energy harvesting model in disaster condition.

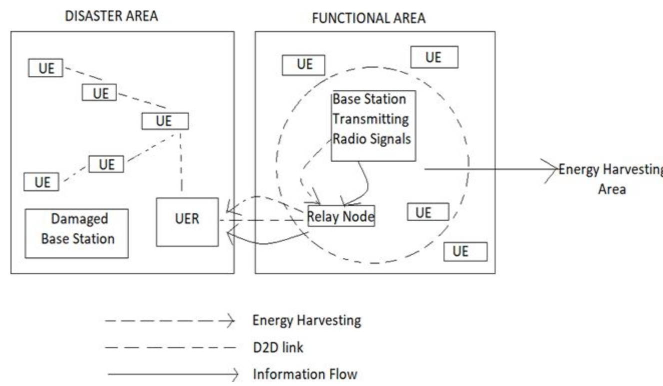

Figure 3: Energy Harvesting Concept in Disaster Situation

Three assumptions are made as follows,

Assumption 1:

The device to device communication that we consider is said to be a wireless communication. Here, the information is transferred from source node S to the destination node D. The transmission takes through the forward relay node (FRN) which is in between the source node and the destination node. The destination node D can act as a Reverse Relay Node (RRN) in another hop in the disaster zone and in the clustering formation phase, the user equipment relay node acts as a cluster head (CH).

Assumption 2:

The relay node R is considered as an intermediate node which acts as an energy constrained node. The relay node gets the energy from the base station i.e., the source node. It first harvests the energy from the source node S and next, this harvested energy is used as a source of transmit power to transfer the source node’s information to the destination node.

Assumption 3:

The relay node can forward the energy and information to the destination node only if the relay node has sufficient energy or else if it can harvest the energy from the base station. There are so many relaying protocols which can be used in this type of system models. In the proposed system model, Decode and Forward scheme is used at the intermediate node i.e., relay node.

In the above Figure 3, there are two coverage areas, functional and non-functional or disaster area. The base station in the functional area transmits the radio signals continuously, so that a relay node in the coverage area or disaster zone is used to get the energy and information from the base station. Once the destination node gets the required energy and the information, it transfers the information to other user equipment. The relay node should be within the energy harvesting area so that it can receive the energy and the information from the source node in the functional area. The energy harvested at the relay is expressed as,

$$E = \tau_1 T \zeta \sum_{k=1}^{K} P_k |l_k|^2 \qquad (1)$$

For each time slot $\tau_1 T$ the energy is acquired and ζ is the energy efficiency, P_k is the power at base station, l_k is the link between source and destination node. To maximize the energy efficiency, the harvested energy is allocated to the cluster with effective gain,

$$E = \tau_1 G_e \qquad (2)$$

3.2 Routing Protocol

Cooperative systems are characterized as fixed, adaptive, and feedback schemes. With the fixed protocol Relay always passes the message to the target while with the adaptive protocol the message is transmitted under a predefined threshold rule which permits independent or non-informal communication. A decode and forward protocol is an adaptive strategy which sets the routers to communicate and distribute information on the wireless network among any two nodes. The routing algorithm determines the route selection. Every router has a previous knowledge of its networks. This information is exchanged first among immediate neighbors and then across the network by a routing protocol. By this way, the routers get the information of network topology. In this routing protocol, decoding of the information takes place firstly and then it forwards the information to the next node. Figure 4 depicts the concept of decode and forward routing protocol.

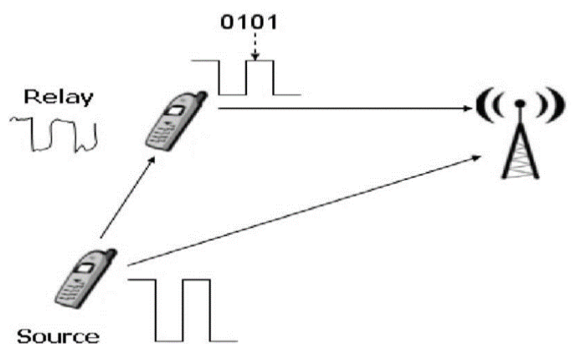

Figure 4: Decode and Forward Routing Protocol

The achievable rate for each cluster is expressed as,

$$R_{k,1} = \log_2(1 + h_{k,1}^2) \qquad (3)$$

The outage probability is defined for the rate below the threshold, it is given by,

$$P_o(R_{k,1} | r_1) = P(R_{k,1} \le r_1) \qquad (4)$$

3.3 Priority Scheduling

Scheduling of the clusters in disaster area is one of the essential tasks in resource management. It is essentially performed at the medium access layer of the base station. It depends on many factors such as number of users per cluster, received signal strength, power level of user equipment and so on. Conventionally, Round-robin (RR) scheduling is performed to assign priority to all the users in a scheduling interval. It doesn't take into account channel quality at all, hence, suffers from low network throughout as some users with deep fade may also be scheduled. Though it provides the best fairness among users, it fails to satisfy QoS requirements in general. It performs well if all the users have similar average signal-to-noise ratio (SNR) all the time which is not the case in a practical scenario.

$$SNR_n = \max\{C_i, i : U_i \in CL_n\}, n \in \{1.....N_C\}$$

(5)

$$EE_k = \gamma = \frac{E[T_i]}{P_T^i}$$

(6)

Hence, a priority based energy efficient scheduling is proposed to optimize the energy consumption among the clusters. Figure 5 shows the proposed scheduling approach with cluster prioritization. For example, C1, C2, C3, and C4 are clusters. Relay node is situated at the boundary of disaster area and functional area. A fully functional base station is located at the center of the operating area. Let h_1, h_2….h_k be the received channel gains of the users in the cluster. Using received signal strengths and the effective energy of cluster the base station prioritizes clusters in the disaster zone. This approach is beneficial for clusters suffering from lack of energy or low power. The cluster with low effective energy is identified and chosen as the primary contact with the relay node. Hence, proper scheduling of clusters might priotize the users and prevent them from disconnecting to the network in emergency times.

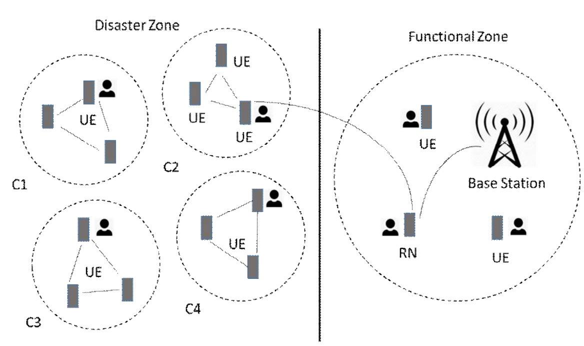

Figure 5: Priority-based Scheduling

4. RESULTS AND DISCUSSION

We consider a scenario of cellular network with uniform UE distribution. A BS is situated in coverage area with sufficient transmit power. We use Matlab simulation tool to analyze the impact of user device variations, energy consumption of user terminals, energy harvesting, and distribution of energy in the clusters. Table 1 shows the simulation parameters used for the study of D2D energy consumption.

Table 1: Simulation Parameters

Parameters	Values
Bandwidth	10MHz
User devices	10-100
Clusters	30
Power at BS	1.5Joules
Data size	1500bytes
UE transmit power	0.25W
Time	300s

Figure 6 shows the variation of outage probability as a function of energy harvesting efficiency ζ over three different cases non-clustering (NC), clustering (EE-C) and clustering with energy efficient scheduling (EES). It is observed that the proposed approach tends to have optimal energy harvest efficiency and hence reduction in outage probability. The chance of D2D communication improves with the help of scheduling and energy harvesting.

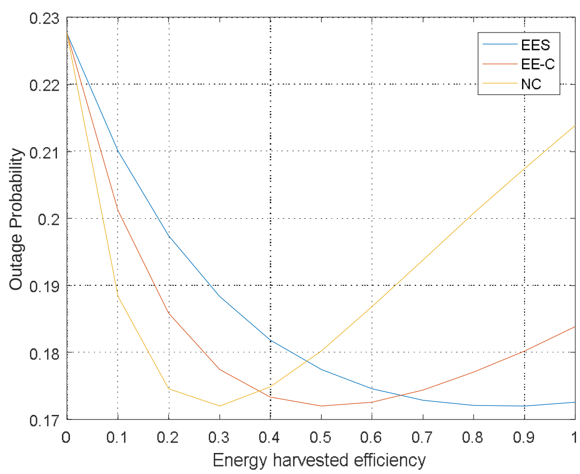

Figure 6: Outage Probability vs Energy harvest efficiency

Figure 7 highlights the impact of user equipment as relay node on the outage probability. It is noticed that the increase in energy harvest efficiency leads to decrease in outage probability and thus transfer takes place through relay node. Thus, the probability of a user equipment to function as relay node increases. More number of users can be served without loss of energy. Prioritization of D2D clusters improves the energy efficiency. Outage probability increases exponentially when there is no possibility of D2D communication.

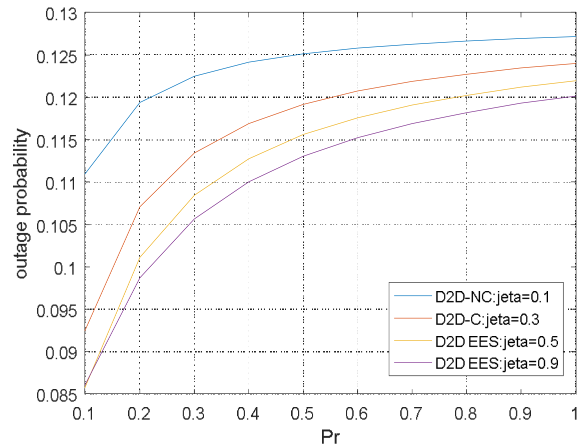

Figure 7: Outage probability vs Probability UE relay

In Figure 8, the total energy consumption in non-clustering communication is plotted for varying number of user devices. The energy consumption increases with the number of user devices. We calculate the overall energy usage of user devices in D2D communication based on both non-clustering and clustering. We note that energy consumption increases exponentially in a non-clustering scenario while in the proposed scheduling method the energy consumption increases almost linearly in the D2D communication paradigm.

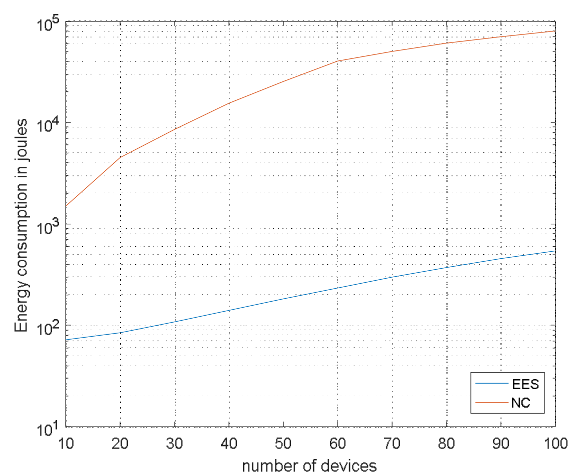

Figure 8: Energy consumption in Clustering vs Non-clustering

Figure 9 plots the energy distribution of user devices in different cases. It can be observed the proposed approach gives better energy savings compared to non-clustering and clustering approaches. This is because, in the proposed scheme the effective energy per each cluster is considered to schedule the users. Also, the received signal strength information is used at the BS to schedule the users. This approach is beneficial to many clusters in the disaster zone which really deprives due to lack of power.

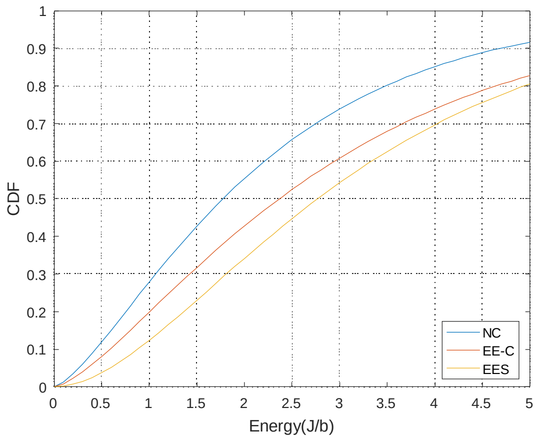

Figure 9: Energy consumption vs CDF

Figure 10 plots the energy efficiency by varying the number of devices. It can be found that the proposed EES scheme reaches maximum efficiency with the increase in devices per cluster. However, the non-clustering approach shows poor performance compared to the other schemes. The energy efficiency with clustering results in maximum value of 0.92. Thus, it can be concluded that EES technique optimizes the energy consumption of devices by efficient allocation and scheduling.

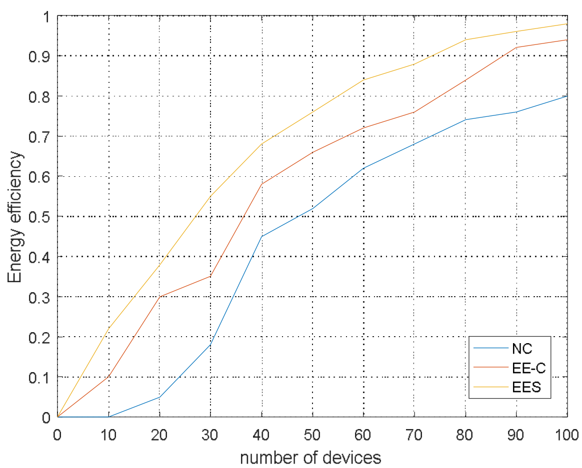

Figure 10: Number of devices vs Energy efficiency

5. CONCLUSION

D2D communication for cellular networks is an advanced method for enhancing network capacity and spectrum utilization through the reuse of cellular network resources. Resource sharing by D2D users and cellular users addresses the energy aware resource management. Three different concepts such as energy harvesting, routing strategy and priority scheduling are used to improve the power consumption during disasters. In order to address the disadvantages from direct communication, a relay mode of communication is proposed as an alternative mode to the current cellular and D2D modes. This minimizes terminal disconnection and allows connection between working area to disrupted zones. The suggested method brought the energy savings for both user equipment nodes and clustering heads, so it is very useful at the time of disasters. From the results it is shown that outage probability can be considered as an important factor to prove whether the D2D communication is efficient. It is also observed that the energy consumption will be less for D2D based communication than the non-clustering communication.

REFERENCES

1. G. Baldini, S. Karanasios, D. Allen, and F. Vergari. **Survey of wireless communication technologies for public safety** *IEEE Commun. Surveys Tuts.*, vol. 16, no. 2, pp. 619-641, Sep 2013. https://doi.org/10.1109/SURV.2013.082713.00034
2. K. Ali, H. X. Nguyen, Q.-T. Vien, and P. Shah. **Disaster management communication networks: Challenges and architecture design** in *Proc. Pervasive Comput. Commun. Workshops (PerCom)*, St. Louis, MO, USA, 2015, pp. 537-542.
3. H. Gao, Y. Shen, and B.Yang. **D2D Communication for Disaster Recovery in Cellular Networks** *International Conference on Networking and Network Applications(NaNA)*, Kathmandu, 2017, pp. 292-295.
4. G.C. Deepak, A. Ladas, and C. Politis. **Robust Device-to-Device 5G Cellular Communication in the Post-Disaster Scenario** *in Proc. 16th IEEE Annual consumer communications and networking conference (CCNC)*. Las Vegas, NV, USA, 2019, pp. 1-6. https://doi.org/10.1109/CCNC.2019.8651832
5. A.A. Salem and T. Alhmiedat. **Energy-Efficient Clustering WSN System for Environment Monitoring Applications** *IJETER*, vol. 8, no. 5, pp. 2126-2132, May 2020. https://doi.org/10.30534/ijeter/2020/106852020
6. A.Asadi, P.Jacko, and V.Mancuso. **Modeling D2D communications with LTE and WiFi**, *ACM SIGMETRICS Performance Evaluation Review*, vol. 42, no. 2, Sep 2014.
7. M. Hunukumbure, T. Moulsley, A. Oyawoye, S. Vadgama and M. Wilson. **D2D for energy efficient communications in disaster and emergency situations** *in Proc. 21st International Conference on Software, Telecommunications and Computer Networks* (SoftCOM), Primosten, 2013, pp. 1-5.
8. H. Nishiyama, M. Ito and N. Kato. **Relay-by-smartphone: realizing multihop device-to-device communications** *IEEE Communications Magazine*, vol. 52, no. 4, pp. 56-65, April 2014. https://doi.org/10.1109/MCOM.2014.6807947
9. K. Ali, H. X. Nguyen, Q. Vien, P. Shah and Z. Chu. **Disaster Management Using D2D Communication With Power Transfer and Clustering Techniques** IEEE Access, vol. 6, pp. 14643-14654, 2018.

10. Z. Lu, G. Cao and T. La Porta. **Networking smartphones for disaster recovery** *in Proc. 2016 IEEE International Conference on Pervasive Computing and Communications (PerCom),* Sydney, NSW, 2016, pp. 1-9.
11. B. K. Chalise, Y. D. Zhang and M. G. Amin. **Energy harvesting in an OSTBC based amplify-and-forward MIMO relay system** *in Proc. 2012 IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP)*, Kyoto, 2012, pp. 3201-3204. https://doi.org/10.1109/ICASSP.2012.6288596
12. B. Clerckx, R. Zhang, R. Schober, D. W. K. Ng, D. I. Kim and H. V. Poor. **Fundamentals of Wireless Information and Power Transfer: From RF Energy Harvester Models to Signal and System Designs** *IEEE Journal on Selected Areas in Communications*, vol. 37, no. 1, pp. 4-33, Jan. 2019.
13. T. Ngo, H. Nishiyama, N. Kato, T. Sakano and A. Takahara. **A Spectrum- and Energy-Efficient Scheme for Improving the Utilization of MDRU-Based Disaster Resilient Networks** *IEEE Transactions on Vehicular Technology*, vol. 63, no. 5, pp. 2027-2037, Jun 2014. https://doi.org/10.1109/TVT.2014.2314462
14. B. H. Jung, H. Leem and D. K. Sung **Modeling of Power Consumption for Macro-, Micro-, and RRH-Based Base Station Architectures** *in Proc. 2014 IEEE 79th Vehicular Technology Conference (VTC Spring)*, Seoul, 2014, pp. 1-5.
15. H. H. Yang, J. Lee and T. Q. S. Quek. **Green device-to-device communication with harvesting energy in cellular networks** *in Proc. 2014 Sixth International Conference on Wireless Communications and Signal Processing (WCSP),* Hefei, 2014, pp. 1-6.
16. D.F. Egbe and B.M. Murimo. **A Resource-aware Service Discovery Architecture for Ad-hoc Mobile Cloud** *IJETER*, vol. 8 no. 6, pp. 2402-2408, June 2020. https://doi.org/10.30534/ijeter/2020/32862020