

D2D Communication and Energy Efficiency on LTE for Public Safety Networks

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Abstract— Communication between rescue teams and people affected by the disaster is of vital importance. However, in the event of a disaster, infrastructures such as roads, bridges, buildings and communication sections can be damaged. Device-to-device communication technology, which allows direct communication between two devices without the need for any infrastructure, such as a base station, is an important solution to overcome the disaster communication problem. In this study, device-to-device communication technology on Long Term Evolution (LTE) for communication after disaster has been presented based on bandwidth and capacity values from point to point on a sample scenario.

Keywords— Device-to-Device Communication (D2D), Post-Disaster Communication, Public Safety Networks (PSN), Proximity Service (ProSe), LTE.

I. INTRODUCTION

The disaster events such as earthquake, tsunami, hurricane, can cause human loss, communication problem and damage to infrastructures. After a disaster event, the need for communication with people and disaster management institutions has vital importance. For example, effective disaster management can be achieved by receiving information quickly and accurately from the disaster area. For this reason, it is especially important to maintain the communication infrastructure. It is possible to see the effects of the new generation communication systems like 4G / 5G in disaster management systems as we have seen in every corner of our lives.

The biggest problem in terms of communication after the disaster event is that the communication infrastructure is damaged (the base stations become inoperable, etc.) or become unusable due to heavy traffic. In order to solve this problem, the studies on disaster communication systems are increasing in recent years. It focuses on the design of architectures, particularly those affected by disasters, which enable people to communicate with outside and rescue teams [1-3].

In the event of the disaster, when existing communication systems and communication equipments are damaged, the

communication with the device to the device (D2D) becomes an important option. This solution is highlighted by the fact that it is sufficient for mobile users (telephone, tablet, etc.) (UE-User Equipment) that have for communication to use alone [4].

In the literature, some of the studies focused on energy efficiency in order to communicate the disaster area using D2D communication with multiple jumps (multihop) [4,5]. The disaster has been modelled as Proximity Service (ProSe) and Public Safety Network (PSN) in version 12 (Release 12-R12) within the scope of 3GPP (3rd Generation Partnership Project). There are also studies which are PSN studies on the use of D2D communication [4-6]. Especially in the USA, a 700MHz frequency band has been allocated to use in PSN networks [6]. In this frequency band, emergency assistance system called FirstNet is cooperated by communicating with the necessary institutions after the disaster situation [7].

In this study, the band capacity values, energy and spectrum efficiency are presented on a sample scenario, that is different from the previous our work [8] for D2D technology, which is the communication option between people and institutions in the disaster zone after the disaster.

The organization of this study consists of the following parts: introduction and LTE general structure and band channels in the first section, D2D communication classification, coverage-discovery status and 3GPP proposed ProSe architecture and challenges in D2D communications under the heading of D2D communication technology in the second section, point-to-point D2D communication on the example scenario in the third section energy and spectrum activity, simulation results and conclusion.

A. LTE Structure

In LTE structure, each subframe's length is 10 ms and it consists of 10 subframes. Each subframe with 1 ms length, comprises two 0.5 ms slots. Each slot consists of seven OFDM (Orthogonal Frequency Division Multiplexing) symbols, respectively. Fig. 1 shows the LTE frame structure within time domain.

In the frequency domain, the system bandwidth is divided into the subcarriers each with a bandwidth of 15 kHz. It forms a sequence of 12 consecutive subcarriers for a slot length. This sequence, known as the Physical Resource Block (PRB), has a bandwidth of 180 kHz [9].

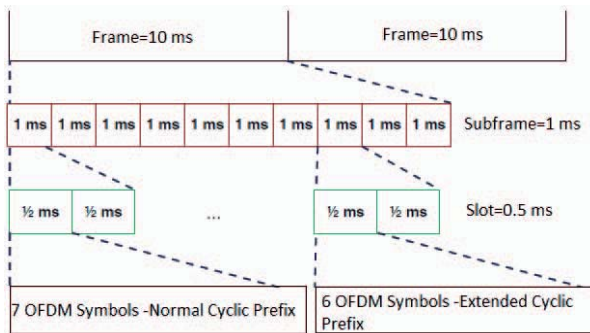


Fig. 1. LTE Frame structure [9].

There are 6 channels customized for LTE, which are given in Table 1 as channel bandwidth and number of resource blocks.

TABLE I. CHANNEL BANDS FOR LTE

Explanation of Channel Bands for LTE	
Channel Bandwidth(MHz)	Number of Resource Blocks
1.4	6
3	14
5	25
10	50
15	75
20	100

II. DEVICE-TO-DEVICE (D2D) COMMUNICATION TECHNOLOGY

D2D communication is done with the help of base station (BS) or between devices outside the coverage area. It is seen as a key solution to the development of 5G technology with the ability to communicate without the BS among the devices themselves [10-12]. By the widespread use of mobile devices and mobile users, today's D2D communications can be considered as a communication solution to the post-disaster situation with the sharing and transmission of games, content (video, photo, etc.).

D2D communication provides low latency and high data transmission at the short distances. In comparison with

conventional cellular communication, D2D provides energy savings and reduce overload density of the cellular network [13]. The first example of D2D communication with the LTE-Advanced (LTE-A) network in the literature is the FlashLinQ mobile communication system developed by Qualcomm [14]. By this technology, FlashLinQ enabled devices can discover automatically and communicate with each other in 1 km coverage area without infrastructure [13].

A. Types of Communication

In studies regarding D2D in the literature, the D2D communication is classified into licensed spectrum in-band and licensed spectrum ISM band (Industrial Scientific Medical) out of the band in cellular networks.

In-band D2D communication is divided into underlay and overlay. D2D and cellular networks use the same spectrum, while D2D and cellular communication use the allocated spectrum to reduce interference in overburden communication in case of underside communication.

Out-of-band classification includes technologies such as WiFi, ZigBee, and Bluetooth. In case of communication with base station support, controlled communication is established among the devices themselves [15]. Fig. 2 shows the D2D communication types.

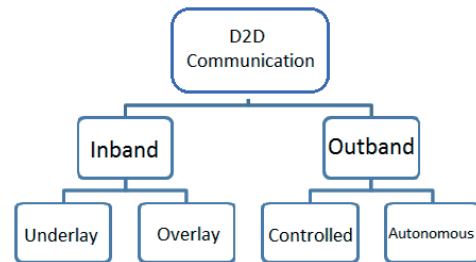


Fig. 2. D2D Communication types [15].

B. Coverage Area and Discovery Status

In D2D communication, the coverage area UE and BS state are defined in three dimensions, within coverage area, partial coverage area, and out of coverage area. It is assumed that all UEs considered within the coverage area of BS to receive service or signal from BS. The partial coverage is that some UEs are outside the BS coverage area and others are outside. In case of out of coverage area situation, it indicates that all the considered UEs are out of the scope of BS and it cannot receive service or signal from a BS [13].

Restricted or open proximity service discovery is a use case of a basic proximity discovery scenario used for any application.

- In case of restricted proximity discovery, a ProSe-enabled UE discovers another UE nearby if it is obtained permission previously. A discovery of friends or co-workers in a social network is restricted by the privacy settings of the discovery UE, which does not include confidentiality as an example of a restricted use case.

- In the case of open proximity discovery, a ProSe enabled UE can find neighboring devices without requiring a license. A store or a restaurant advertisement are considered as examples of open use case. Because shops and restaurants are open to exploitation for all possible ProSe-enabled UEs.

C. System Architecture

Fig. 3 shows the D2D architecture which is proposed by 3GPP[16]. New architectures added to this architecture of the context of UMTS Terrestrial Radio Access Network (E-UTRAN) and Evolved Packet Core (EPC) developed to traditional LTE architecture are as follows [13];

ProSe application server, includes ProSe capability to create application functions as specific organizations of the case of social media in the commercial situation or Public Safety. These applications represent reference points for 3GPP entities, and communicate with an application of the UE.

ProSe UEs application, provides for members of the Public Security group and other nearby UEs used to communicate. ProSe functions include authorization and configuration of UEs for discovery then direct communication, besides internet networking opportunity through a correct reference point to third party applications. The PC1-6 and SGi in Fig. 3, refer to seven interfaces and the Uu refer to air interface. S1 is defined for linking new entities and connecting to classic LTE.

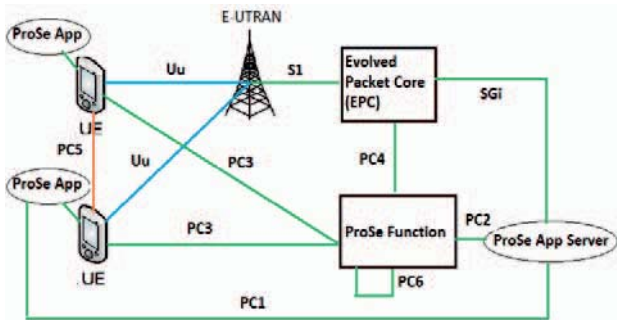


Fig. 3. D2D architecture proposed by 3GPP [13,16].

D. Challenges in D2D Communications

Some of the problems to be solved in the field of D2D communication technology are as follows [10-13]:

- Device discovery procedures to identify the presence of other UEs in the area or area,
- Connection establishment strategies for correct selection (resource allocation) of the spectrum to be used in D2D radio links between the respective UEs,
- The avoidance interference mechanisms, which are possible to coexist between the cellular network and the D2D UEs,
- New device designs and mobility management,
- Energy consumption and security.

III. AN EXAMPLE SCENARIO USING D2D COMMUNICATION

In the example scenario shown in Fig. 4, where D2D communication is used to provide communication after the disaster, one of the D2D scenarios proposed by 3GPP is taken as a reference [16].

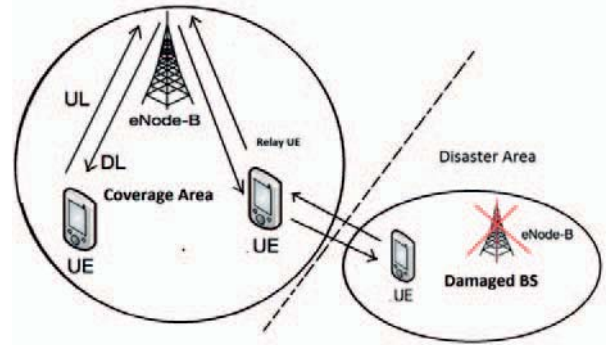


Fig. 4. Post-disaster communication scenario [8].

A. Energy-Spectrum Efficiency and Capacity

It is important to use energy and spectrum efficiency, capacity, frequency band effectively.

Signal to Noise Ratio (SNR) is calculated in Eq. (1) without interference (I) [17]. PD denotes the transmitter power (watt) for D2D, rD stands for the distance (m) between relay UE-UE (disaster area), α is the standard deviation for D2D and σ represents path loss exponent for an urban area.

$$SNR = PD/rD^\alpha \cdot \sigma^2 \quad (1)$$

Equation (2) presents the band capacity (C) for each bandwidth [4,5]:

$$C = \sum_{i=1}^N BW \cdot \log_2(1 + SNR) \quad (2)$$

In Equation (3), the energy efficiency (EE) is calculated according to the power of the device (PD), bandwidth, SNR and the noise for each bandwidth [17].

$$EE = \left(\frac{BW}{2 \cdot PD}\right) \cdot \left(1 + \frac{1}{SNR}\right) \cdot \log_2(SNR + 1) - \log_2(e) \quad (3)$$

Equation (4) gives the spectrum efficiency (SE) formula as the ratio of the bandwidth of each capacity value [4,5].

$$SE = C/BW \quad (4)$$

The post-disaster communication scenario was run according to the simulation parameters given in Table 2.

TABLE II. SIMULATION PARAMETERS FOR POST-DISASTER COMMUNICATION SCENARIO

Explanation of Parameters		
Explanations	Symbols	Values
Distance (m)	rD	0-100
Carrier Frequency(Mhz)	CF	700
Transmitter power(dB)	PD	UE=23 , eNB=46
Subframe Time(ms)	T	1
Path Loss Exponent	α	3
Standard Deviation(dB)	σ	12
Resource Blocks	RBs	[6-14-25-50-75-100]
Bandwidth (Mhz)	BW	[1.4-3-5-10-15-20]

Fig. 5 shows the capacity curves according to the SNR values. The values represent in X-axis as the SNR and other values represent in Y-axis as the capacity for Fig.5. As can be seen from this figure, the change in the channel capacity starts from less values than $10e-2$ SNR value.

As can be seen from this figure, the capacity values (Mbit / joule) for each bandwidth (BW1-6) are $C1 = 0.29$, $C2 = 0.64$, $C3 = 1.06$, $C4 = 2.13$, $C5 = 3.20$, and $C6 = 4.27$ at the $SNR=0.1597e-8$, respectively. It has been observed that as the distance increases, the SNR ratio decreases gradually and the capacity values increase exponentially.

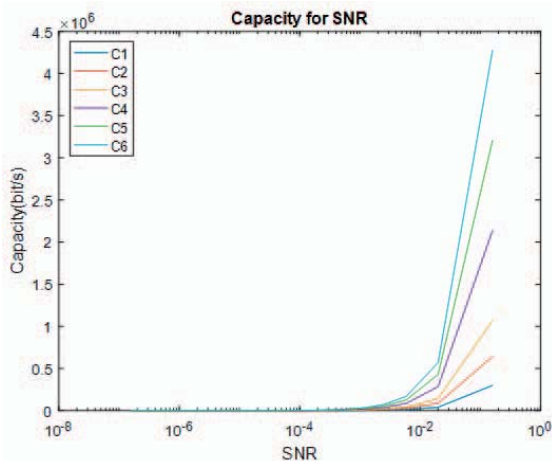


Fig. 5. Channel capacity curves according to SNR values

Fig. 6 shows the change in energy efficiency for each bandwidth according to the spectrum. Spectrum efficiency is observed to increase to the existing bandwidths depending on the increase on capacity. The energy efficiency values (Mbit / joule) obtained according to the bandwidth (BW1-6) were $EE1 = 23.23$, $EE2 = 49.77$, $EE3 = 82.95$, $EE4 = 165.9$, $EE5 = 248.9$ and $EE6 = 331.8$. It has also been observed that the increase in bandwidth due to the decrease in the SNR ratio also increases the energy efficiency.

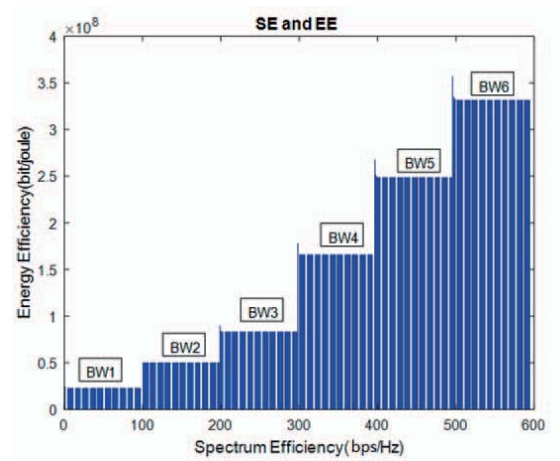


Fig. 6. Energy Efficiency change of according spectrum

Fig. 7 presents the energy efficiency values (EE1-EE6) obtained for each bandwidth. It has been observed that the increase in energy efficiency is twice as high as the bandwidth (eg. BW3-BW4 or BW4-BW6) depending on the capacity increase.

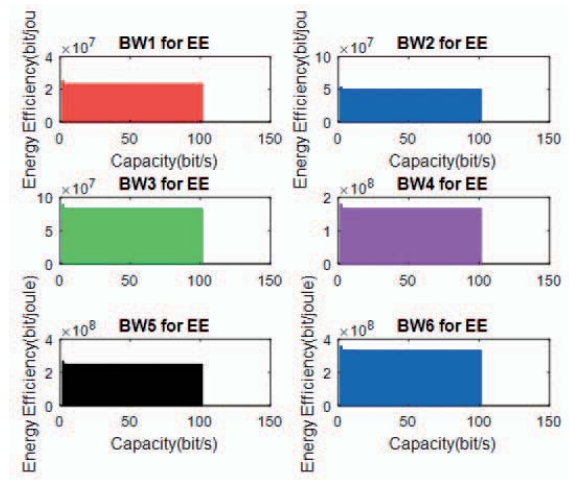


Fig. 7. Energy Efficiency-Channel capacity according to bandwidths.

Fig. 8 shows the change in energy efficiency in terms of the distance. For each bandwidth, it can be seen that the energy efficiency values tend to decrease as the distance increases. For example, the energy efficiency decreased to $EE1 = 23.23$ (Mbit / joule) and $EE6 = 331.8$ (Mbit / joule) for 100m distance respectively, while $EE1 = 24.99$ (Mbit / joule) and $EE6 = 357$ (Mbit / joule) for 1m distance. For a UE with a low bandwidth, energy is reduced less, while for a UE with a higher bandwidth, the energy is further reduced.

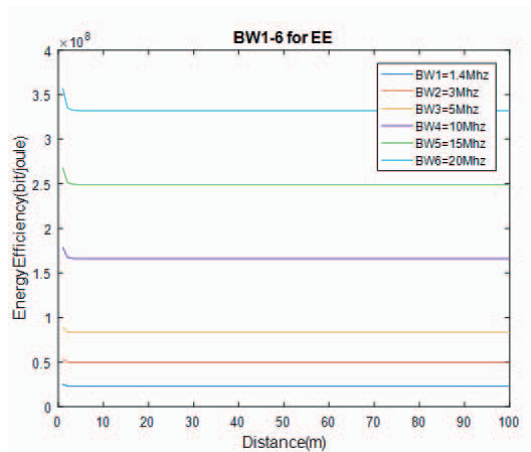


Fig. 8. Energy Efficiency change of according to distance

IV. CONCLUSION

D2D communication can be a solution option for the communication if the post-disaster base station is damaged or is unusable. The distance and handshake number for the D2D communication has shown in a certain time period relative to the target distance (D) in our previous study [8]. In addition to this study, the bandwidth, capacity, energy and spectrum efficiency calculations in the LTE standard are evaluated on the same scenario. Energy and spectrum efficiency values were observed to be related to the capacity case and capacity for each bandwidth according to the noise ratio. When the communication distance between D2D is increased, it is observed that the energy efficiency of UE with a large bandwidth decreases faster than that of UE with the small bandwidth.

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