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A Survey on Device-to-Device Communication with Internet of Things in Cellular Networks

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Abstract: Device to device communication is an amazing tool applied to the cellular network to offer more spectrum to the base station and decrease the communication delay, also, the Internet of Things is used to facilitate the transfer of data for the groups of devices simultaneously, the aim of this paper is to review both technologies in past, current, and expected future based on the preview studies, both technologies are expected to support the realism of 5G cellular networks, the findings of survey is demonstrated in some challenges involve compatibility between IoT objects, internet protocols and interference management, the proposes solution of this challenges is in demand to improve the performance of next generation of cellular networks.

Keywords: Device to Device Communication; Internet of Things; Cellular Network.

1. Introduction

The Device to Device (D2D) communication is a direct connection between a pair of proximity devices without passing the signal over the Base Station (BS). In conventional cellular networks, the D2D elements (such as mobiles, computers, and others) are unable to communicate with each other directly, but the signals are travel from the transmitter to receiver via base station, in this case, the transmitter propagates a signals with high power to the receiver and causes severe interference that degrades the efficiency of communication system [1], [2]. D2D communication will become a prominent technology in the future of cellular networks due to the fast growth of the indoor communication, and the recent studies have shown that more than 70 percent of wireless communication originated indoors [3], [4]. The smartphones are growing rapidly due to the daily demands, this growth requires more spectrum and supplementary technology to support the 5G cellular networks, and consequently, D2D communication is prospective to be an essential part of the Internet of Things [5]. The Internet of Things (IoT) is deemed as a great technology that permits the sharing of data between manifold devices without any intervention, and it is formed to be available on request at any time and place [6], [7]. The idea of the IoT is to connect multiple devices in the specific area to provide high-grade services. the IoT encompasses a vast number of heterogeneous devices with several features connected concurrently through an intelligent routing to achieve a straight and efficient D2D communication [8], [9]. The future of cellular communication and mobile networks was studied by the leading communication organizations in the world, they investigating and refining the design and infrastructure of the 5G network, they expected that the traffic will be rise in the cellular network and may reach to 70 till 2020 compared to 2010 and thousand times by others predictions. Also, they introduced the D2D communication system to offer a large spectrum to the cellular networks in the IoT ecosystem [10]. The aim of this paper is to provide a survey of the IoT application and D2D communication, we studied the state-of-the-art of both technologies with expected features in the future of cellular networks. The rest of this paper is organized as follow: Section II presents the D2D communication, concept, applications, and investigation of some

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problems in addition to the mathematical equations of increasing data rate transmission, Section III involves internet services survey, IoT concept, and applications. Section V includes the conclusion.

2. Device To Device (D2d) Communication

In the past, the handling of information between devices can be achieved by using an electrical connection to transfer data through physical cables and connectors on both sides of the communication, due to some problems faces connectors the wireless radio frequency is proposed to solve the electrical connection problems for an indoor short distance without human intervention. Fig. 1 illustrates the conventional cellular networks, and the electromagnetic signal is propagated in the air to the BS and from the BS to end users [11].

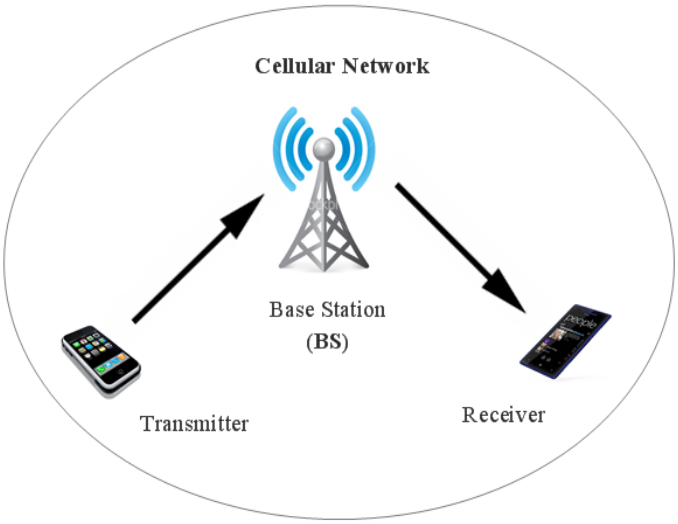

Fig. 1 - Conventional cellular network

The principal of D2D communication is investigated comprising usage scenarios, structure design, technical features, and in addition to the area of recent research[12], the conclusion of authors expected that the D2D communication provides a real-time response in IoT ecosystem and become an essential part to accomplish the 5G cellular networks. The spectrum sharing of D2D communication below cellular network was introduced by using game theory to improve the system capacity and decrease inter-cell interference (ICI) when the D2D coexist within the common area of neighboring cells [13], [14], like as shown in Fig. 2.

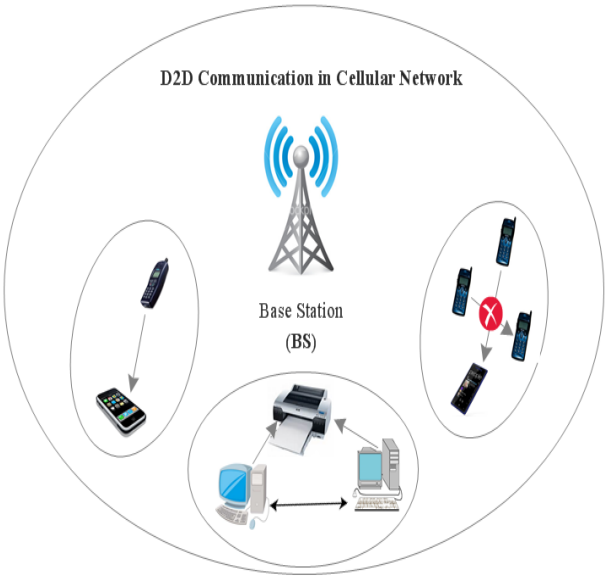

Fig. 2 -D2D communication under cellular network

The D2D was devoted to European 5G research project to be the backbone of huge services in 2020, the universal ideas of D2D is displayed in Fig. 3, and the channel paradigm of D2D is demanded more concentration to improve the indoor communication system clearly in case of many D2D works concurrently [15], [16],[17].

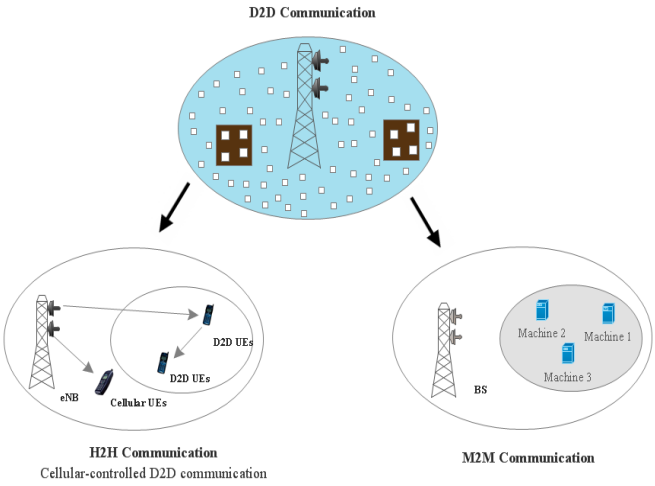

Fig. 3 -General D2D communication system

The performance of D2D is influenced by sharing the same spectrum with cellular network in IoT ecosystem, due to the inadequacy of spectrum in the communication scheme a new structure was studied by using small base station as relying to improve the data rate of D2D in the IoT ecosystem [18], furthermore large number of devices will be connected to each other in IoT to convey the data in the more smart, proper, and efficient way. The IoT-D2D resource assignment technique was introduced to support the D2D to convey data immediately between IoT objects with highest transmission rate in the indoor environments [19]. The reuse of downlink resource method is reviewed in the group of various D2D links and cellular users underlay cellular network, the sum-rate maximisation problem was formed for the D2D communication, whereas safeguard the cellular transmission [20]. Couple algorithms are introduced for the common D2D-Cellular user matching, of the transmission duration to both online and offline power harvesting processes at the D2D paths, and of the power distribution, the introduced algorithms are validated by simulation, and the result has shown that the online algorithm produced a satisfactory performance than the offline algorithm. a comprehensive survey of various highly advanced methods for the interference management was investigated to decrease the interference between D2D and cellular networks, and two kinds of interference called co-tier and cross-tier are presented [21], The MIMO transmitter is proposed to overcome the interference among D2D and provide the highest SINR [22], recent trends may integrate the D2D communication with visible lights in the IoT ecosystem due to the high and free spectrum of visible light technology. Furthermore, to perform a direct communication among D2D users, the least distance to guarantee the connection is needed, and the movement of devices deemed as one of the key difficulties in the D2D communication to produce a successful transmission and reception among devices. The synchronization content between D2D communications in the dynamic environment was introduced in [23][24][30], and couple strategies of synchronization are investigated in terms of the delay to improve the energy performance. Also, it was analyzed theoretically and simulated through a city section mobility model, and the interference between devices is depicted in Fig. 2 refers to the red cross circle. The sector antenna at the cells is investigated to produce a spectrum sharing for both D2D and cellular network connections [22]. The applying of D2D communication in the cellular network represent a strong key to proof the future reality of 5G systems. The writers of this article review the performance of D2D based transmission in the deployment of IoT services to achieve a very low latency, and the performance evaluation of the proposed mechanism is validated by the simulation [27]. The outcomes confirm that the narrowband IoT is capable to support an endless number of IoT objects with ultra-low latency, and the whole of narrowband IoT and D2D communications represents a proper practical solution. Also, the conveying of D2D communication with twin batteries for IoT devices are studied, the analysis determines an optimal resource allocation technique that promotes the decreasing of total energy consumption when the signals are conveying through picocell [18]. Fig. 4 depicted the mechanism of Relay and Direct D2D communications.

The transmission data rate of the ^{nth} signals from the source device to relay Base station is given by expression below:

$$C_{n,j}^{SR} = W_{n,j}^{S} \log_2\left(1 + \frac{P_{n,j}^{S} h_{n,j}^{SR}}{N_0 W_{n,j}^{S}}\right) \qquad (1)$$

Where $W_{n,j}^{S}$ refer to the bandwidth assigned to the all-source devices. $P_{n,j}^{S}$ represent the transmission power of all source devices, and $h_{n,j}^{SR}$ is the channel gain of links between multiple source devices and the relay BS j.

The transmission data rate of signals from the relay BS point to the nth destination device expressed by:

$$C_{n,j}^{RD} = W_{n,j}^{R} \log_2\left(1 + \frac{P_{n,j}^{R} h_{n,j}^{RD}}{N_0 W_{n,j}^{R}}\right) \qquad (2)$$

Where $W_{n,j}^{R}$ refer to the bandwidth allocated to the all destination devices. $P_{n,j}^{R}$ represent the transmission power of the signals from jth relay BS to the destination devices, and $h_{n,j}^{RD}$ is the channel gain of links between the relay BS j to the nth destination device. No intermacrocell interference as supposed by the authors, and consequently, the total transmission data rate from the source to the destination of mth SD pair is given by:

$$C_{m,j}^{SD} = W_{m,j}^{S} \log_2\left(1 + \frac{P_{m,j}^{S} h_{m,j}^{SD}}{N_0 W_{m,j}^{S}}\right) \qquad (3)$$

Where $P_{m,j}^{S}$ represent the transmitted power of various source device in picocell j, $h_{m,j}^{SD}$ and $W_{m,j}^{S}$ are the channel gain and allocated bandwidth among various SD devices in picocell j respectively, N_0 refer to the power spectral density. The result of the new architecture was improved the resource allocation of the network, optimized the data rates, and reduced the energy consumption of all signals through relay BSs, the VLC may require in order to enhance the obtained results in the IoT ecosystem. The power optimization problem of the coexistence of multiple D2D communication was studied underlying the cellular networks, and the problem was investigated by considered the fast and low fading in the channel state information. Additionally, the received power was supposed to be equal for all D2D elements to guard the cellular receiver against the interference, the result shows that multiple D2D element links can use the same band beside the cellular network with high performance, and this result may be optimized more in the future through using visible light communication [28]. Various optimization methods applied to the spectrum allocation for the D2D model was proposed [26], and the rating of optimization problems and the appropriate key algorithms are investigated. The most studies were concern in the in-band communication due to its high ability to control the licensed spectrum that provides a better reduction for interference problem, on the other hand, it's difficult to control the unlicensed spectrum and the QoS may decreases with the interference among the users, and this may open a new thinking about the interference mitigation techniques and methodologies for the next generation such as the mm-wave and visible light communication.

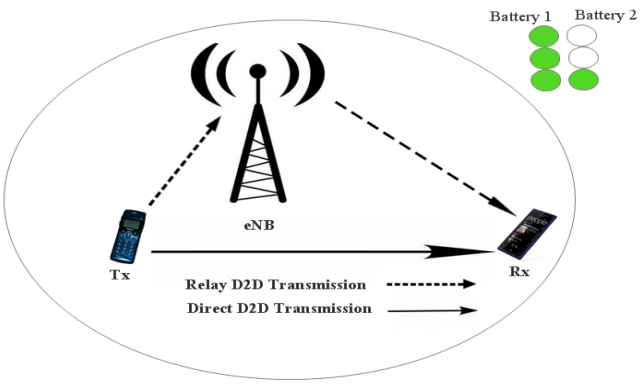

Fig. 4 -Relay and Direct D2D Communications

3. INTERNET OF THINGS (IoT)

The internet is deemed as most great and powerful production in all history of humanity, and IoT schemes are in the road to fill the gap between poor and rich, promote sharing of the globe's resources to those who require them most, in addition, help us appreciate our planet to be more proactive and less reactive [29] , the IoT is distributed rapidly based on the Cisco investigation depicted in Fig. 5, it shows the dramatical changed in the growing of distributed devices per population around the world from 2010 to present. IoT aims to facilitate and simplify the number of connected devices to be greater than people to invent new applications.

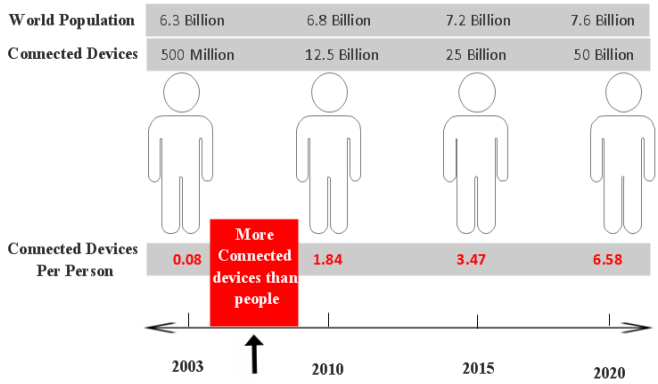

Fig. 5 -Current status & Future prospective of IoT

The IoT considered as one of the most common services in mobile cloud computing, the mobile statistics traffic will extend to 15.9 hexabytes for each month through 2018 based on the Cisco prediction survey, the interference reduction and energy efficiency have participated to the development of a novel mobile heterogeneous network (mobile HetNets), the mobile HetNets provide the D2D communication without latency and its increase the total spectral efficiency via reducing the number of connected devices in BS, additionally, the HetNets model was created and simulated by MATLAB [30]. Fig. 6 is depicted the general application of IoT ecosystem.

Fig. 6 -General application of IoT ecosystem

IoT technology is applied to tracking and monitoring system for the real-time data to save and optimize the power consumption. A wide number of applications in IoT ecosystem are investigated on design, production, and services for various scenarios [31]. The effective modeling, standardization, security, and heterogeneity of devices in the IoT represents the main challenges in the future that faced by the manufacturing and companies and may require more studies to optimize the power consumption of different application scenarios.

The convergence among 5G and IoT are presented based on some allowing technologies studied [32], and multidisciplinary analyses are required to pass the challenges of the future IoT ecosystem [33]; a novel model is introduced and investigated extensively to allow mutual assessment, and optimization of multidisciplinary properties containing hardware design, connection, and data processing.

Now the IoT is developing every day and become one of the effective tools toward an emerging of the smart life and the world sequentially. A survey of IoT and their applications are studied in [34], the result confirms that about 50 billion objects and devices will be connected to the internet in 2020 based on the Cisco record. Also, it has a marketing value able to makes an impact on the economy in the future and will be the dominant size at 2025 such as shown in Fig. 7 [35].

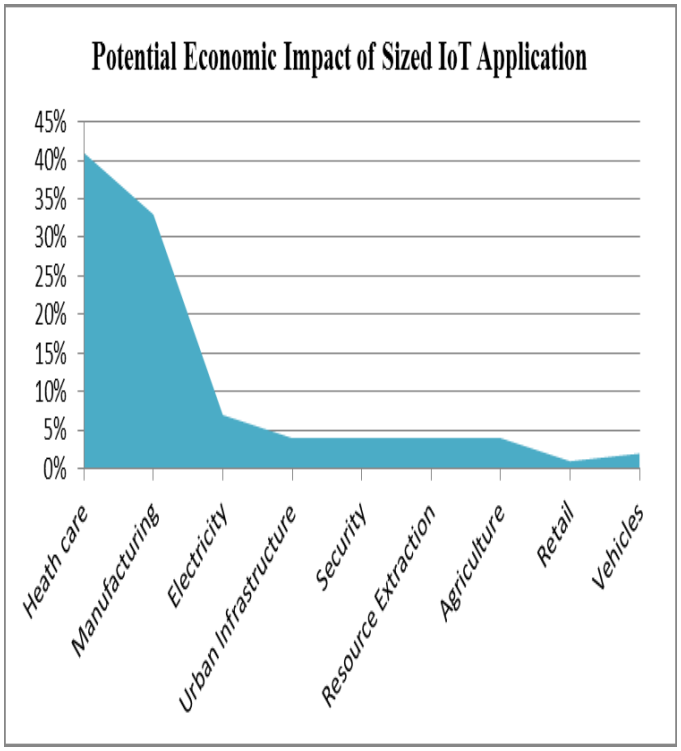

Fig. 7 -Estimated market share of predominant IoT applications by 2025 [35]

A comprehensive survey of the IoT is investigated by showing the application of IoT in a broad environment; also, middleware requirement was reviewed to solve the non-homogeneity of physical objects and devices in the IoT [36]. Also, the ongoing and current directions of the IoT are investigated besides evolving by numerous organizations, universities, and industrials through the world to fill the gap of integration and standardization between different applications and devices in the IoT system, in addition to the security and others key challenges [37]. Moreover, IoT has used in forecasting of natural disasters over the world and deemed especially at a few years ago due to the large numbers of the catastrophic, and it's known as an important application for the IoT recently [38].

The IoT network model becomes realism due to the huge increases in the devices that connected to the internet, and the incorporating to exchange the information between devices efficiently is required [39], also, IoT network contains a three essentially fragments called sensing, communication and management that used to produce the information, establish a connection, conveying and gathering the information, in addition to processing management respectively.

Day by day the technologies will be increasing by the unexpected way especially in the communication and network fields, and the amounts of connected devices were exceeding the number of the population in the world based on the Cisco report in 2008 – 2009, this report lead and support the emerging of the IoT system. Many difficulties for the IoT and web of things WoT are presented in [40], the huge works of many groups and companies are needed due to the advances in the smartphones, it may represent a key success of the IoT. From the study of D2D communication and IoT technology, we obtain some practical issues illustrated in the challenges of this review. The findings of this survey are illustrated in the challenges below and may require more attention by the academia, and industries to open and visualization the realism of next generation of cellular networks.

4. Challenges

4.1 Internet Protocols

The internet services in most of the developing counties are still lacking and worked under the IPv4, and the smartphones and devices changing rapidly, more suggestion and solutions may require from the telecommunication cooperations and regularities of those ones to apply the IoT professionally in various applications.

4.2 Compatibility between IoT objects

The whole devices and smartphones around the globe are made by different companies, and organization with different software and hardware components, the compatibility between all these devices is in demand to facilitate the convey data professionally, also, more studies by an academics and industries are required.

4.3 Interference management

The cellular network of manifold D2D communication and cellular users connected simultaneously suffer from severe interference due to the spectrum sharing, and its causes two kinds of interference, the first is the interference between multiple D2D communication elements and the second is D2D elements with the cellular user, this interference causes a decreasing in the received power and SNR, and its degrade the performance of communication system, more solutions and investigations may in demand to mitigate the interference in the 5G networks.

5. Conclusion

D2D communication and IoT are played a great role in the developing and enhancing the 5G cellular network, the aim of this paper is to review both technologies in past, current, and expected future based on the preview studies and demonstrates the challenges. In spite of frequency reuse and low communication delay for the D2D communication its still, suffer from the severe interference between D2D themselves and cellular users, also for the IoT technology is offering a wide range of applications with high flexibility for connected devices, the IoT suffers from the compatibility between objects and may require more attention by industries fields. Both technologies open a gate widely for the developer and researchers around the world to solve its challenging in order to support the future of cellular networks.

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