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Review on M2M Communications Using D2D Communications in Cellular Networks

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Abstract—Machine-to-Machine (M2M) communications enable networked devices and services to exchange information and perform actions seamlessly without the need for human intervention. They are viewed as a key enabler of the Internet of Things (IoT) and applications, like mobile healthcare, telemetry, or intelligent transport systems. Wireless communications services, cellular communication systems are going towards small cells with small transmit powers. Meanwhile device-to-device communication (D2D) is seen as a promising idea to increase the performance of wireless networks. In D2D, users in vicinity communicate directly without going through base station. In this paper we review the concept of M2M communications using D2D communications in cellular networks. We use full duplex D2D communication with up-link and down-link required in D2D in cellular systems.

Keywords— Device-to-Device (D2D) communications, full-duplex, Machine-to-Machine (M2M) communications, up-link, down-link

I. INTRODUCTION

Increasing demand for wireless communication is leading to congestion of radio spectrum, which is an expensive and scarce resource. So better utilization of radio spectrum becomes more important and new technologies are required for this purpose. Device-to-Device communication is seen as a new technology component which can improve the spectral efficiency of the cellular systems.

In device-to-device communication, users directly communicate with each other instead of going through base station. UE1, UE2, UE3 are the users. Since now a days users require high data rates specially for local connectivity services like gaming, video sharing, offloading the data transfer from base station and establishing direct communication between users will be highly beneficial for the system. Fig.1 shows the general idea of D2D communication.

D2D is categorized into two groups, in-band and out-band shown in Fig. 2. In out-band, D2D links use unlicensed band such as ZigBee or Wi-Fi, while in-band, D2D link uses licensed cellular bands. The connection is establishing in out-band D2D which is called autonomous out-band or by the base station which is called controlled out-band [2].

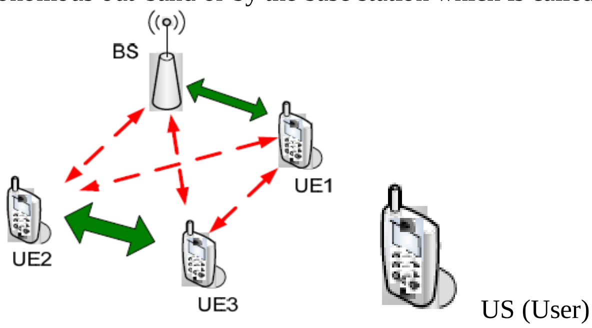

Fig. 1 Device-to-Device (D2D) Communications [1]

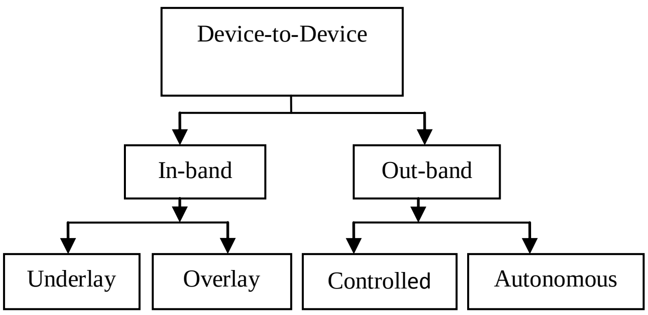

Fig. 2 Device-to-Device (D2D) Classification

In-band D2D also has two categories, D2D users can have share the same resources as some of the cellular users which is called as underlay in-band or dedicated radio resources, which is called overlay in-band.
The problem of deciding on whether D2D users should communicate through base station (cellular mode) or directly (D2D mode) is an important issue. The problem of deciding on whether D2D users should communicate through BS (cellular mode) or directly (D2D mode) is an important issue.

During the last two decades, the trend in wireless communication technologies has shifted from the traditional voice-centric "man-to-man" mobile communications to data-centric "man-to-machine" mobile communications and further shift towards "machine-to-machine". A typical example of machine-to-machine mobile communications is car-to-car (C2C) or vehicle-to-vehicle (V2V) communications. As the name refers, in M2M communication systems, all entities in the network are in motion. These entities can either be mobile users or vehicles [3].

Fig. 3 Machine-to-Machine Communication [4]

Machine-to-Machine (M2M) communication describes algorithms, mechanisms and technologies that enables networked devices, wired and wireless, and services to exchange information or control data without explicit human intervention. M2M communication is an important aspect of traffic control, remote control, logistic services, supply chain management and telemedicine. It forms the basis for a concept known as the Internet of Things (IoT). Key components of an M2M system include RFID, sensors, a Wi-Fi cellular communications link and autonomic software programmes to help a networked device interpret data and make decisions.

Telemetry is the most well-known type of M2M communication, which has been used since the early part of the last century to transmit operational data. In Fig. 3 shows, M2M communications, all machines like mobile, van, home, laptop, computer, ambulance etc are first send the signals to the BS and then they are communicate with each other. In this paper, we communicate two devices directly without send the data to BS and later into M2M communication in cellular networks.

II. LITERATURE REVIEW

Mobile M2M communications face many technical challenges despite the promising benefits in terms of revenue opportunities and cost reductions in maintenance and resources. M2M devices are usually small in size and not expensive, introducing energy, bandwidth, computation, and storage constraints to communications [5].

A. D2D Supports in Cellular Networks

Now day's cellular networks offer wide coverage areas, high data rate, and decreasing latency, and therefore they are a key enabler of D2D communications. D2D communication is considered to be one of the key technologies in future wireless systems to increase spectral Efficiency. Providing direct communication between devices will decreases latency and also offload data from base station. The problem of radio spectrum congestion due to increasing demand for wireless communications services, cellular communication systems which have small transmit power and are going implemented in device-to-device communication are investigated and it was shown by results that currently available full-duplex radios can be used in device-to-device communication. Power control, resource allocation and interference-limited-area are used to deal with the interference that is the result of resource sharing [2].

B. D2D Communications and Network Coding

In 2009, the author Afif et al. [1] Introduced two concepts which have not been present in cellular systems for IMT-Advanced so far-Device-to-Device (D2D) communication and network coding. Both of these concepts are used to increase the efficiency of cellular communication systems, especially from a network point of view. The result is to achieved sufficient SINRs multi-antenna receivers are required that allow device-to-device communication when the D2D connections re-use cellular resource within the cell. The author shown that user grouping in a multi-user networks improves substantially the capacity of network coding. As a solution, introduced a low complexity user grouping strategy and showed that when applied with a window size of 6, the user grouping algorithm provided mean capacity gains of 34% and 16% as compared to random network coding.

C. Cooperative D2D Communications

Shalmashi et al. proposed a cooperative device-to-device communications in order to combat the problem of congestion in crowded communication areas such as shopping mall and open air festivals.

The idea is allowed a D2D transmitter which is act as an in-band relay for a cellular link and at the same time transmits its own data in the downlink. It observed that the D2D receiver is able to cancel the cellular user signal which can improve the achieved data of the D2D link in most cases [6].

D. Formation of Devices

The device-to-device communications have several benefits. The author Pankil et.al.Discussed what can be their blocking probability in cellular cells as well as formation of D2D group [7]. The blocking probability describes for D2D communication which devices are ready for communicate with each other. It was concluded that the all devices get connected it means there is no blocking of the devices for communication when the traffic load is less. As the load increases, the blocking probability also increases.

E. Survey on D2D

The surveyed literature showed that D2D communication can improve the spectrum efficiency greatly. The author Arash Asadi et.al categorised D2D communication in two major groups, namely, in-band and out-band [8]. He faced the major issue in underlay D2D communication is the power control and interference management between D2D and cellular users. Overlay D2D communication does not have the interference issue because D2D and cellular resource do not overlap. And the interference level of the unlicensed spectrum which is called as out-band is uncontrollable, hence QoS is a challenging task in highly saturated wireless areas.

F. M2M Support in Wireless Networks

M2M devices using radio technologies have some problems from cellular networks and wireless networks. In mobile-to-mobile cooperative communication systems, the author Batool Talha introduced the analysis of a large variety of M2M fading channels and presents the state-of-the-art regarding the modelling in cooperative systems. In this, the author modelled and analysed narrowband M2M fading channels in cooperative network systems under line-of-sight (LOS) as well as non-line-of-sight (NLOS) propagation conditions. The performance of dual-hope-multi-relay cooperative systems introduced over M2M fading channels with Equal Gain Combining (EGC) and line-of-sight propagation conditions was evaluated. It is concluded that, in a dual-hope-relay-system with Equal Gain Combining (EGC), improves the systems performance of line-of-sight components in the transmission links [9].

G. M2M Support in Cellular Networks

The cellular networks offer wide coverage areas which have high data rate, and decreasing latency, and therefore they are enabler of M2M communications. Marwat et al. [10] argue that, even in the presence of regular mobile M2M traffic and LTE traffic cannot be considered negligible, and it can have some impact like dramatic impact on the LTE network performance in terms of Quality of Service (QoS).

H. Energy Efficient and Reliable M2M

Now a days energy efficient communications are extremely important in challenging areas where access to mains power is difficult. Andrius et al. proposed a new approach which is called as Clone-to-Clone (C2C) has the potential to reduce the traffic between end points, improve network performance and reduce power consumption of device. In [11], it was shown that, the M2M communication is much more powerful than that and C2C is an new approach to solve the issues hindering development of the network applications in the next generation.

The author Andrius et al, introduced Energy Efficient and Reliable (EER) and all research issues related with the deployment of M2M architecture of M2M communication. “Green Allocation with Zone Algorithm” (GAZA), this algorithm used to achieve Energy efficient and Reliable M2M system for energy efficient and dynamic traffic grooming in WDM networks [12].

I. M2M in Vehicular Networks

In [3], the author Booysen et al. shown that M2M communications in the vehicular networking context and he was investigated areas where M2M principles can improve vehicular networking. Since connected vehicles are network of machines that are communicating with each other, preferably autonomously, vehicular networks can benefit a lot from M2M communications support. Then they highlighted the specific applications, requirements and protocols relating to M2M based vehicular networks.

Finally, they performed analysis of the challenges faced by M2M systems. The standardization of communication interfaces in a network was the most significant challenge with high mobility and variability of components. Managing privacy and security in such a dynamic network requires further attention.

III. ETSI (EUROPEAN TELECOMMUNICATION STANDARDS INSTITUTE) M2M ARCHITECTURE

The European Telecommunication Standards Institute (ETSI) M2M architecture is currently the reference architecture for global, end-to-end, M2M service level communications, and is being adopted by main European telcos

[13]. The system architecture is based on current network and application domain standards, and it is limited extended with M2M Applications and Service Capabilities layers (SCLs). SCLs are Service Capabilities (SCs) on the Network domain, M2M Device, or M2M Gateway. SCs provide functions to be shared among different M2M applications. The functions of a SCL include, but are not limited to, registration of applications, provision of means for storage, policy-based selection of communication means for information delivery, support for multiple management protocols, or support of remote management of gateways and devices [14]. Fig. 4 shows the high level ETSI M2M system architecture as defined in ETSI Technical Standard
(TS) [15]. the key entities in M2M are

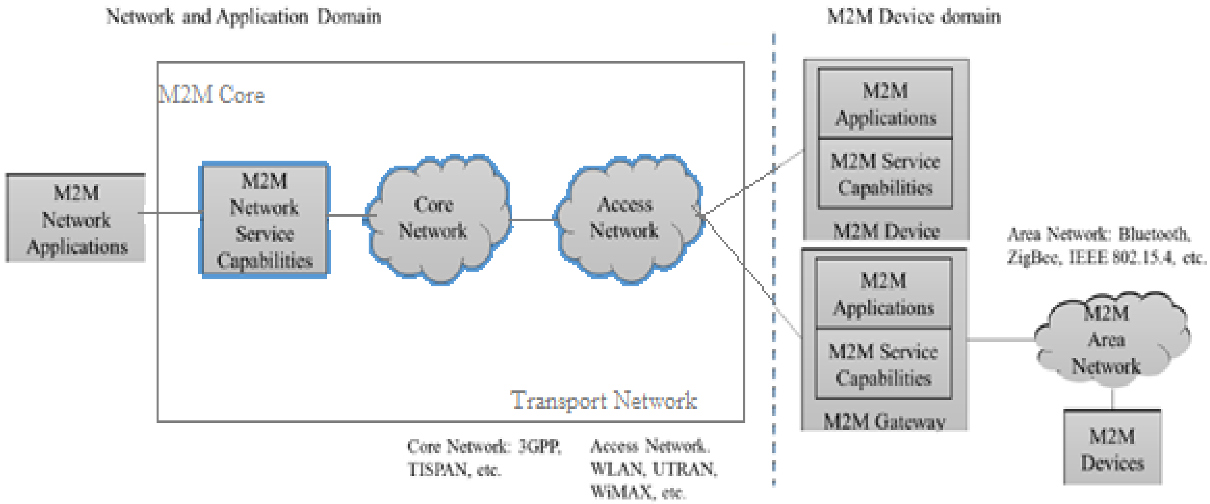

Fig. 4 European Telecommunications Standards Institute (ETSI) Machine-to-Machine (M2M) high level system overview [15]

- M2M Gateway: - M2M devices interconnection to the network and their inter-operability.
- M2M Device:- a device that runs application using M2M capabilities and network domain functions.
- M2M Area Network: - it provides connectivity between the M2M devices, ETSI M2M gateways, compliant and non-compliant with ETSI M2M.
- M2M Applications: - applications that use Service Capabilities accessible via open interfaces and run the service logic.
- M2M Network and Application Domain: - it provides connectivity between M2M applications and M2M gateways.
- M2M Network Applications:- applications, in the Network and applications domain, that use Service Capabilities accessible via open interfaces and run the service logic.

The Network and Application Domain is formed by the Transport Network, the M2M Core, and the Access Network. The Access Network provides connectivity between the M2M Device.

The Transport Network, Domain and Core Network provides connectivity within the Application Domain and the Network. Satellite, UTRAN, UWB, WLAN, or WiMAX technologies are used in the Access Network. The M2M Cores are composed by the M2M Network SCs and Core Network (CN). The Core Network provides IP connectivity, roaming capabilities within the M2M Core. The technologies provided by TISPAN or 3GPP can be used in the CN.

The M2M Device domain is formed by M2M Area Network, M2M gateways and M2M devices. The M2M devices are connected directly to the network and application domain using the Access Network, or they can connect first to an M2M gateway using the M2M Area Network. In first case, the devices are run an M2M applications and an SCL, and provides access to Access Network for the M2M Device, since the M2M Device has only an M2M Application running, but no SCL, and it is not compliant with ETSI. The Area Network provides connectivity between M2M gateways and M2M devices, and can be built on Bluetooth, ZigBee, M-BUS, UWB or IEEE 802.15.4 technologies.

To better illustrate some entities, the author described a map and storyboard in M2M. Fig. 5 shows an high-level view of storyboard [13]. In an M2M ecosystem, Jonathan, a user, connect his smartphone which acting as an M2M Gateways, to collect information from sensor, M2M devices, over Bluetooth using an M2M Application.

The M2M Gateway send the data to a Network SCL (NSCL) using 3G, which have main function is to manage the data. In this case, for the backup storage purpose , the NSCL stores the data and send the content to a medical Network Application.

The M2M Management functions are all the functions required to manage M2M SCs and M2M applications in the Network and Applications Domain, and the Network Management functions have functions required to manage the access, transport networks and core. The management functions include the configuration management, performance management, fault management and software upgrading management. M2M Application life cycle

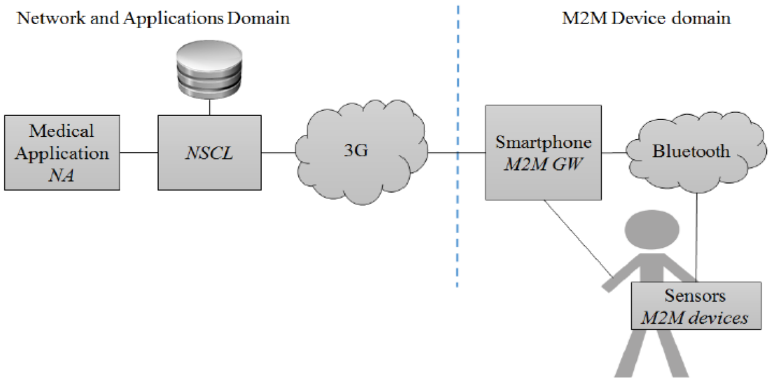

Fig. 5 High-level view of the storyboard [13]

management includes removing, upgrading and installing applications in the M2M Gateway or Device. The M2M Device management includes the configuration management of the M2M Gateways or Devices. The M2M Area Network management includes configuration management for the M2M Area Networks.

IV. PROBLEM FORMULATION

Many papers are published related to D2D and M2M communications separately. And more research also carried out in these two different topics. Now, in this paper we combine D2D and M2M communications. First we communicate two devices directly instead of going to base station, increase the spectral efficiency and then they are communicate with M2M in cellular network.

V. FULL-DUPLEX D2D COMMUNICATION WITH

A. Up-link resource

Consider that D2D users are using the same radio resources as uplink transmissions in the cell. In this case, base station receives interference from D2D transmissions. D2D receivers will also receive interference from uplink transmissions of the cellular users that share the same resources as D2D link. In $A_1$and $A_2$are interference limited areas for D2D users D1 and D2, and radius of these areas are $d_1$and d_2 respectively refer Fig.6. Throughput of the system in the presence of D2D link is increased, the amount of this gain depends on the resource allocation and power control methods. On other hand, while using full-duplex radios, throughput is affected by the residual of self-interference. Z_T is total throughput of the system when D2D link is activated

For half-duplex (HD) D2D:

$$Z_{T,HD} = Z_C + Z_{Cj,HD} + Z_{D,HD} \qquad (1)$$

For full-duplex (FD) D2D:

$$Z_{T,FD} = Z_C + Z_{Cj,FD} + Z_{D,FD} \qquad (2)$$

In the above equation, Z_C is throughput of cellular users that are not sharing resources with D2D users, $Z_{Cj,HD}$ and $Z_{Cj,FD}$ rate of cellular users that exploit the same resources as D2D users in half-duplex and full-duplex mode respectively. Rate of half-duplex D2D link is $Z_{D,HD}$ and for full-duplex D2D denote the rate by $Z_{D,FD}$.

We consider γi to be the SNR of CUi at BS, $\gamma_{j,HD}$ and $\gamma_{j,FD}$ to be the SINR of the cellular users that share the same resources as D2D users while D2D is in half-duplex and full-duplex mode. So the rates for cellular and D2D users are

$$Z_C = \sum_{i=1, i\neq j}^{M} \log_2(1+\gamma_i) \qquad (3)$$

$$Z_{Cj,HD} = \sum_{j=1}^{M} \log_2(1+\gamma_{j,HD}) \qquad (4)$$

$$Z_{Cj,FD} = \sum_{j=1}^{M} \log_2(1+\gamma_{j,FD}) \qquad (5)$$

When D2D users operate in half-duplex mode, D2D user D_2 is transmitting and D2D user D_1 is receiving. Denote the SINR of D2D user D_1 as γ_{Dl}. Rate of the D2D link is

$$Z_{D,HD} = \log_2(1+\gamma_{Dl}) \qquad (6)$$

When D2D users use full-duplex mode, both of D2D users transmit and receive at the same time and the throughput of FD D2D link rate is

$$Z_{D,FD} = \sum_{l=1}^{2} \log_2(1+\gamma_{Dl}) \qquad (7)$$

In SINR equations for cellular transmissions, we consider P_{Ci} to be the transmit power of $CU_i$and $G_{Ci,BS}$ channel gain

between CU_i and BS. P_j is the transmit power of cellular user that is using the same resources as D2D users and $G_{Cj,BS}$ is the channel gain between CU_j and BS, and $I_{Di,Cj}$ is interference from D2D transmissions to CU_j.
SINR for half-duplex mode is

$$\gamma_{j.HD} = \frac{P_{Cj} . G_{Cj,BS}}{N_0 + I_{D2,Cj}} \quad (8)$$

SINR for full-duplex mode is

$$\gamma_{j.FD} = \frac{P_{Cj} . G_{Cj,BS}}{N_0 + I_{D1,Cj} + I_{D2,Cj}} \quad (9)$$

N_0 is additive white Gaussian noise in all the equations.

B. Down-link resource

In this presents the downlink transmission resources are being shared with D2D users. In this case, D2D receivers will receive interference coming from base station. Cellular users, which share the same resources as D2D users, will also have interference because of D2D transmissions. Selecting the cellular users for resource sharing is important because of these interferences. Since cellular communications is the primary service, quality of service in cellular downlink transmissions needs to be guaranteed. For this purpose interference limited area method is used to select a group of users for resource sharing that would not face harmful interference from D2D transmissions.

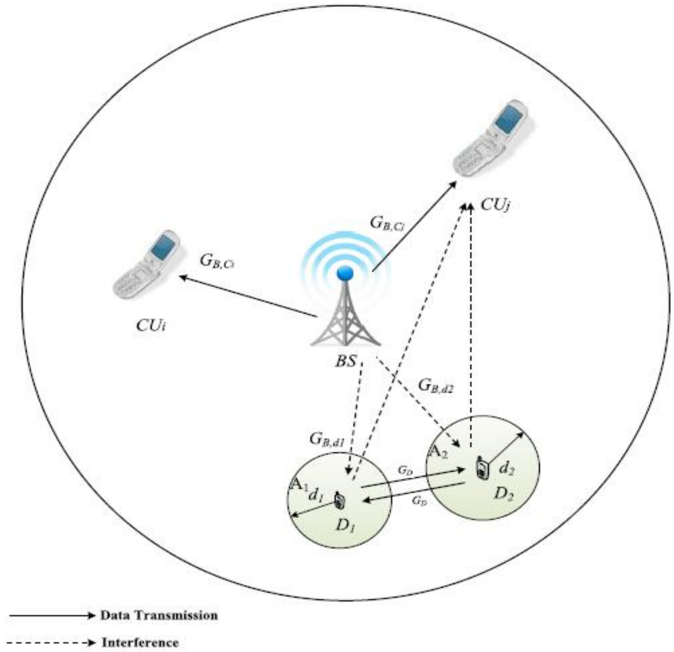

Fig. 6 D2D System Model [2]

To minimize the interference on D2D link, we select the user with minimum transmit power from the group of users selected in ILA (Interference-limited-area) method. System model of D2D communication with downlink resource reuse. In the system model, A_1 and A_2 are interference limited areas for D2D users D_1 and D_2 and radius of these areas are presented by d_1 and d_2 respectively refer Fig. 6. The rates in the system can be written as

$$Z_C = \sum_{i=1, i\neq j}^{M} \log_2(1 + \gamma_i) \quad (12)$$

$$Z_{Cj,HD} = \sum_{j=1}^{M} \log_2(1 + \gamma_{j,HD}) \quad (13)$$

$$Z_{Cj,FD} = \sum_{j=1}^{M} \log_2(1 + \gamma_{j,FD}) \quad (14)$$

When D2D users operate in half-duplex mode, D2D user D_2 is transmitting and D2D user D_1 is receiving. SINR of D2D user D_l is denoted as γ_{Dl}. Rate of D2D link is

$$Z_{D,HD} = \log_2(1 + \gamma_{Dl}) \quad (15)$$

When D2D users use full-duplex, both of D2D users transmit and receive at the same time and D2D link rate is

$$Z_{D,FD} = \sum_{l=1}^{2} \log_2(1 + \gamma_{Dl}) \quad (16)$$

In SINR equations for cellular transmissions, we consider P_{Ci} to be the transmit power of CU_i and $G_{BS,Ci}$ channel gain between BS and CU_i.P_j is the transmit power of cellular user that is using the same resources as D2D users and $G_{BS,Cj}$ is the channel gain between BS and CU_j, and $I_{Di,Cj}$ is interference from D2D transmissions toCU_i. ICI is the Inter-cell interference. SINR for the cellular users in downlink without interference from D2D is

$$\gamma_i = \frac{P_{Ci} . G_{BS,Ci}}{N_0 + ICI} \qquad (17)$$

SINR for cellular users with half-duplex D2D resource sharing is

$$\gamma_{j.HD} = \frac{P_{Cj} . G_{BS,Cj}}{N_0 + I_{D2,Cj} + ICI} \qquad (18)$$

SINR for cellular users with full-duplex D2D resource sharing is

$$\gamma_{j.FD} = \frac{P_{Cj} . G_{BS.Cj}}{N_0 + I_{D1,Cj} + I_{D2,Cj} + ICI} \qquad (19)$$

VI. M2M FADING CHANNELS UNDER

A. *line of sight (LOS)*

Modelling of M2M channels with line-of-sight (LOS) components have motivations behind this comes from the fact that such models are flexible enough to accommodate asymmetric channel conditions. Besides, LOS fading channel models easily reduce to those models that correspond to NLOS propagation conditions. Modelling M2M fading channels with LOS components is more reasonable, since such models can be reduced to those associated with NLOS propagation conditions. It is not necessary that LOS propagation conditions are available in all the transmission links. However, LOS M2M models provide reasonable flexibility to accommodate mixed LOS and NLOS conditions in different machines.

B. *Non line of sight (NLOS)*

The M2M communications describe under non-line of sight (NLOS) propagation conditions. This channel models can be developed based on the geometry of the scattering environment. The multipath propagation channel in any mobile system and wireless communication system efficiently described with the help of proper statistical models. For example, the Rayleigh distribution is considered to be suitable for model fading channels under NLOS propagation conditions in classical cellular networks. NLOS propagation conditions are considered for all transmission links. It is further assumed that there is no direct transmission link between the source mobile station and the destination mobile station.

VII. CONCLUSION

In this paper, we described concepts key to the development of M2M and D2D communications systems. In this paper we communicate two devices directly without going to BS and later into M2M communication in cellular networks. Providing direct communication between devices will decreases latency and also offload of data from BS. A D2D user provides higher spectral efficiency but also causes mutual interference between cellular and D2D users by using full-duplex technique.

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