Device to device communication and its application in future networks

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Abstract

Device to device communication is a novel technology for future wireless network. It opens new opportunities for the researches but also brings lots of unsolved challenges Conventional network uses indirect communication between two user equipments whereas device to device communication uses direct communication between two user equipments. This paper illustrates ongoing research challenges of device to device communication and its application areas for future wireless network.

Keywords: *Device to device communication, 5G, LTE-A, Service discovery*

I. Introduction

Device to device communication is defined as direct interaction between two mobile user equipment (UEs) under the coverage of cellular network using licensed cellular spectrum or unlicensed spectrum. Bluetooth, Wi-Fi Direct are examples of unlicensed band D2D communication whereas LTE Direct is an example of licensed band D2D communication. In traditional cellular network is UEs communicate through base station but in D2D, two UEs or multiple UEs communicate directly among themselves. Inband D2D describes the scenario where mobile UE utilizes uplink and downlink cellular spectrum to establish D2D link. Due to use of licensed cellular spectrum it enables secure data transmission and ensures Quality of Service (QoS) requirements compare to unlicensed band communication [1]. Fig.1 shows during downlink cellular User Equipment (UE) get signal power from eNodeB but that cellular UE also get unwanted signal from D2D transmitter because D2D transmitter and eNodeB uses same resources for their respective links e.g. downlink and UE2UE link.

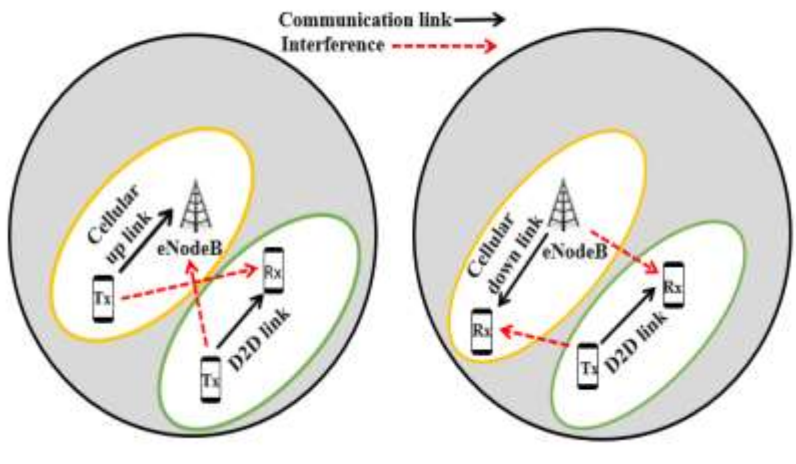

Fig.1. Illustration of Interference problem

Similarly, D2D receiver receives signal from D2D transmitter but it also receives interference signal from eNodeB because that eNodeB transmits signal using same resources for downlink. Therefore, an interference management scheme needs to implement during downlink so that interference cannot break the Base Station to User Equipment (BS2UE) link as well as UE2UE link[2]. Precoding is one of the most promising IC techniques which have been reported in various literatures for interference cancellation in MIMO channels. It has been reported that by the help of channel state information a precoding matrix index and code book can be formed to utilize at MIMO transmitter and receiver for interference cancellation purpose. Binary power control algorithm, geometric distance constraint approach, graph coloring method, Hungarian algorithm, relay assist network approach, game theory approach are popular techniques reported till date[3,4]. In most of these literature maximum throughput or sum rate, ergodic capacity, outage probability, spectral efficiency, transmission power, SINR are considered as performance evaluation matrices. The objectives of interference management are minimization of Cellular Interference on nearby cellular link, Minimization of Cellular Interference on D2D link, minimization of D2D interference on cellular link and minimization of D2D interference on nearby D2D link. In this research work, we have formulated interference management problem for relay assist D2D network in three different conditions as illustrates in Table 1.

Table 1 Three interference region

Condition 1	**Interference power< D2D link signal power**
Condition 2	Interference power = D2D link power
Condition 3	Interference power > D2D link power

Two-tier D2D architecture

In this section, architecture of two-tier device to device communication has been illustrated. There are four types of D2D communication scenarios e.g. (A) Operator assist device act as a relay (OADR), (B) Device assist relay (DAR), (C) Device assist direct communication (DAD) and (D) Operator assist direct communication (OADC). In OCDR model, operator has full control on all devices which are participating in device to device communication. Here one user equipment serves as a relay node. That UE offloading base station's traffic to other user equipments which are located at cell edge and having poor cellular coverage. Base station is unable to provide high speed data service directly to them because of distance constrain. Therefore, relay UE is at full network coverage and have sufficient resources is sharing radio resources to other UEs. Relay UE may be awarded incentives by the operator for providing this service. In this scenario, other UEs getting high speed data traffic from base station only if relay UE allows to utilize its bandwidth. On the other hand base station has full control on All user equipments. Base station can decide resource allocation and pricing policies for all user equipments, whereas other UEs need to discover relay UE by an appropriate service discovery protocol to get data offloading service from relay UE. In DAR scenario, a UE relay and providing services to other UEs. Communication between two UEs is only possible if any of them shares its resources. In this case base station has no role to play. Devices are controlled by a relay device which has supreme authority to establish D2D communication link. Resource allocation policies fully depends on devices rather than operator. Devices in this scenario should ensure interference not to have with other devices of same tier or macro tier while communicating with themselves. In case of DAD scenario two devices directly communicates between them in full duplex mode without base station. Resource allocation is controlled by devices rather than base station. In case of OADC, two UEs communicates with each other under the supervision of base station. Resource allocation and D2D link establishment policies are decided by base station only. Each of these two tire scenario having their own merits and demerits. Operator control scenarios e.g. OADR and OADA is preferable where security is more concern and centralize monitoring is prime priority. Device control scenarios are preeminent in case of proximity based file exchange services and local data off-loading services among devices where a dedicated frequency band can be allocated to the devices.

II. Technical challenges of D2D two-tier network

In this section we have presented various technical challenges and recent research updates of D2D two tier network. First and foremost challenge is to design efficient service discovery protocols for device discovery and direct communication. Proximity service discovery is a process to discover UEs in close proximity for D2D communication. It includes both device discovery and service discovery.There are two types of service discovery protocols already exists for distributed network, named as reactive protocol and proactive protocol. A reactive protocol allows user equipment to discover and send service request to the neighbour UEs. In a device control scenario devices wish to discover another device for direct communication may use a reactive protocol for link establishment. Therefore, reactive protocol initials device tier communication link directly without intervention of base station. After receiving a service request, A UE may accept or reject the request by sending an acknowledgement to the UE who has initiated the request. In proactive service discovery protocol, base station periodically transmits location information of a group of nearby UEs who has registered for device discovery service and willing to do device to device communication. A UE can accept available request or may participate for device to device communication directly after sending an acknowledgement message to the base station. Base station holds all information related to location address and initiates D2D communication. Proactive protocol is suitable for operator control architecture such as OADR or OADA. As base station need to broadcast location information of devices periodically and all devices also need to be active all the time therefore it consumes more power than reactive protocol. Service discovery protocols in licenced band are reported in 3GPP release 12. According to 3GPP there are two protocols. Direct discovery protocols without help of base station and Evolved packet core (EPC) assist discovery protocols [3, 4]. These protocols work in LTE-A architecture as shown in Fig.2. According to this architecture, each user equipment has an inbuilt client application known as D2D proximity service discovery application. This application helps to establish a connection with D2D proximity application server using PC1 link. This server holds location information of all registered UEs under E-UTRAN. A proximity service function which is connected to D2D proximity application server via PC2 link is utilized by concern UEs to get information about D2D service registered UEs. Home Subscriber Server (HSS) authenticates the UE. Mobility Management Entity (MME) stores UE profile related proximity service information. SLP provides UE location information using SUPL. Feasibility study of these scenarios in 5G NR is still an uncovered area of research [5, 6].

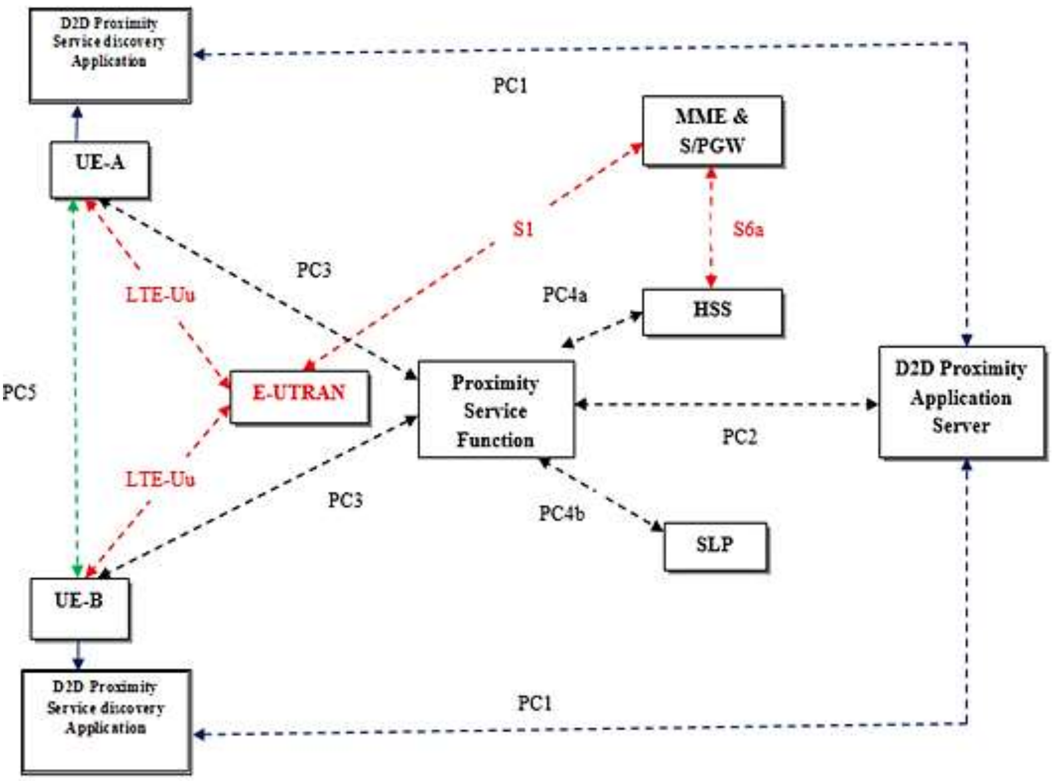

Fig.2. D2D communication in Long Term Evaluation-Advanced

The second important research challenge is to design appropriate resource distribution and interfering signal power supervision technique for D2D link establishment [7-9]. In a two tier network interference may degrade performance of the network in device tier as well as in cellular tier. Inbound device to device communication allows to reuse uplink or down link frequency band for assigning radio resources to the D2D users which creates interference problem to the existing cellular user. More the power level of D2D link makes the cellular link weaker. Hence, various power control techniques has been reported to overcome this problem.The objectives of interference management are minimization of Cellular Interference on nearby cellular link, Minimization of Cellular Interference on D2D link, minimization of D2D interference on cellular link and minimization of D2D interference on nearby D2D link[10]. To overcome interference challenges mode selection based approaches are preferable [11]. In this strategy, three different modes are defined by administrator during allocation of resources to the devices e.g. cellular mode, reuse mode and dedicated mode. This modes are selected by operator based on received channel state information (CSI). CSI depends on received signal to noise plus interference ratio, signal outage probability and channel throughput requirement at the destination UE.Let $P_{i,j}$ is the transmitted power of transmitter of i^{th} D2D pair on the j^{th} time frequency block, then signal power to interference power plus noise ration can be calculated as, $\gamma = \frac{P_{i,j}\, h_{i,i}}{P_{k,j}\, h_{ki} + No}$ and throughput of i^{th} D2D pair on the j^{th} resource block can be evaluated using Shannon's theorem of channel capacity, e.g. C (P_{ij}) =W log2 (1+$\frac{P_{i,j}\, h_{i,i}}{P_{k,j}\, h_{ki} + No}$), where W=channel bandwidth, h_{ii} = channel gain, h_{ki}=channel coefficient of interference link. N_o = Gaussian noise power, $P_{k,j}$= transmitted power in cellular link.Fig.3 shows conceptual flow chart of mode selection based resource allocation technique. Another approach to control interference is to use precoding technique at the D2D transmitter [11]. Codebook based precoding can be utilize for this purpose. Base station need to be aware about the channel state information for the implementation of codebook based precoding. At the receiver, interference signal can be demodulated and used to cancel interference which will improve signal to interference pulse noise ratio.

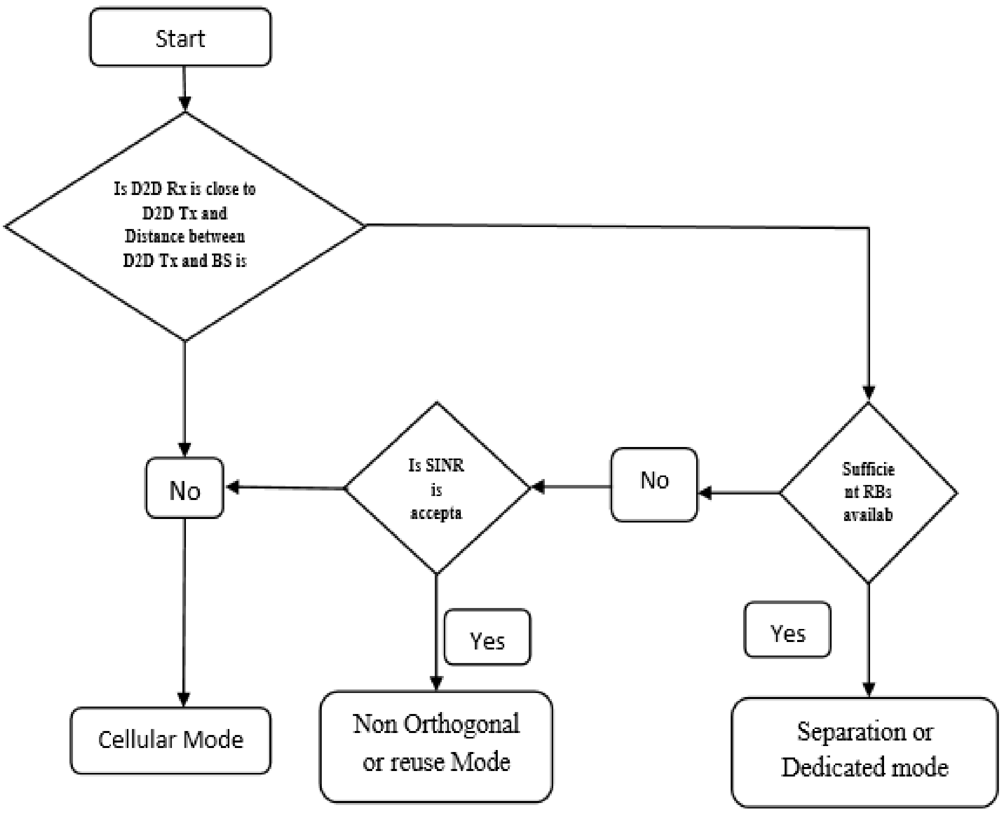

Fig.3. Flow chart of mode selection based resource allocation technique.

Third most important research challenge in two tier cellular architecture is to design of appropriate pricing model. Operator control scenarios e.g. OCDR and OCDC as discussed in section-III, allows base station to decide resource allocation policies and pricing strategies. An incentive based approach is preferable in this regard. According to this approach, incentives will be provided to UEs which will act as a relay node and provides data offloading services to other UEs. Incentive can be given inform of additional bandwidth, additional loyalty services and concession on monthly bill. This technique will encourage more no of UEs to be participated in D2D communication and hence increase profitability of the operator. A utility function can be defined for OCDR scenario as [12], U=B $\log_2$ (1+x γ)-H B P+$\overline{B}$ $\log_2$ (1+ x $\overline{\gamma}$), Here, B is the BS to UE-A link bandwidth. x is defined as spectral efficiency. γ is signal to noise ratio. The first term of this equation i.e. B $\log_2$ (1+x γ) provides the revenue of UE-A. Second term of the equation i.e. HBP describes the charges that need to pay to the operator. H is defined as total no of hops between base station and relay node.

III. Conclusion

In this paper, we have illustrated device to device communication scenario in future wireless network. Also, various technical challenges such as interference management, device discovery algorithms, pricing strategy has been discussed. This paper also provides a solution to overcome interference problem based on orthogonal precoding technique. The proposed technique is based on mode selection and can be used for future wireless network.

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