Design and Analysis of Service Discovery Protocols for D2D Communication in 5G Wireless Network

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Abstract

D2D communication is a novel paradigm in fifth generation mobile communication system. It opens up new opportunities for the researches but also brings lots of unsolved challenges. One of such challenge is to design optimal service discovery protocol for proximity based applications such as context aware messaging, vehicle to vehicle communication, emergency communication etc. In this article we envisioned feasibility study of designing service discovery protocol in a two-tier 5G wireless communication network with so called traditional cellular tier and device to device tier.

Keywords: *Device to device communication, 5G, Service discovery.*

I. Introduction

Service discovery protocols are defined as a set of rules to search nearby devices intended to communicate among themselves. There are two types of service discovery protocols e.g. distributed network protocols and centralized network protocols. Example of distributed network protocol are reactive protocol and proactive protocol whereas example of centralized network protocols are Push mechanism based direct discovery protocol and Network assistance based EPC level protocol. Faustin Ahishakiye et al. in [1] reported two types of service discovery protocol i.e. reactive and proactive. The main idea of the reactive protocol is that User Equipment which proposes to begin Device to device communication with another User equipment initiates proximity service discovery request by means of a pull service detection process, whereas proactive protocol is originated by base station or eNodeB which is serving user equipments before any device to device tier requests has been established. This method is known as push service discovery. Here base station transmit periodic messages to all user equipments to register in device to device service discovery application. The intended UE gives replies for establishing D2D service. Table 1 shows comparison of existing service discovery protocols.Device to Device communication using licenced cellular spectrum band is a novel approach in LTE-A standard which has been introduced in March 2011 by 3GPP release 12[2]. D2D is going to be integral part of 5G cellular network. Short range D2D communication using unlicensed band is already exist and also commercially available. For example, transferring of files between two UEs using blue tooth, exchanging information among UEs with the help of mobile apps and Wi-Fi, Mobile hotspot applications, NFC applications are already exist [3]. But all these techniques belong to unlicensed band communication, they do not use existing cellular spectrum for resource sharing. Therefore they are not secure and also not manageable centrally by the base station or eNodeB. It has been reported in [4] that spectrum sharing is possible between licensed cellular network and infrastructure less wireless network. Moreover D2D user can communicate among each other using the same resource spectrum as the cellular user uses to communicate with base station. It is possible to overcome interference challenges during sharing of same resources with D2D and cellular user by means of power control technique. [5]

Table1. Existing service discovery protocol

Network Types	Distributed Networks (MANETs/ WLAN/WiFi-Direct)	Centralized Networks(LTE-A)
Device Discovery Mechanism	Proactive and Reactive	Direct discovery EPC assist discovery
Operating Frequency Band	Unlicensed ISM band	Licensed Band
Service Discovery protocol types	Carrier Sense Multiple Access	Direct discovery: Push mechanism based protocol EPC level discovery: Network assistance based protocol(Ref:ITU 3GPP release 12)
Limitations	1. Security Challenges 2. Resource allocation and management challenges 3. Protocol Overhead problems	Protocol design challenges in case of out of coverage area of eNodeB

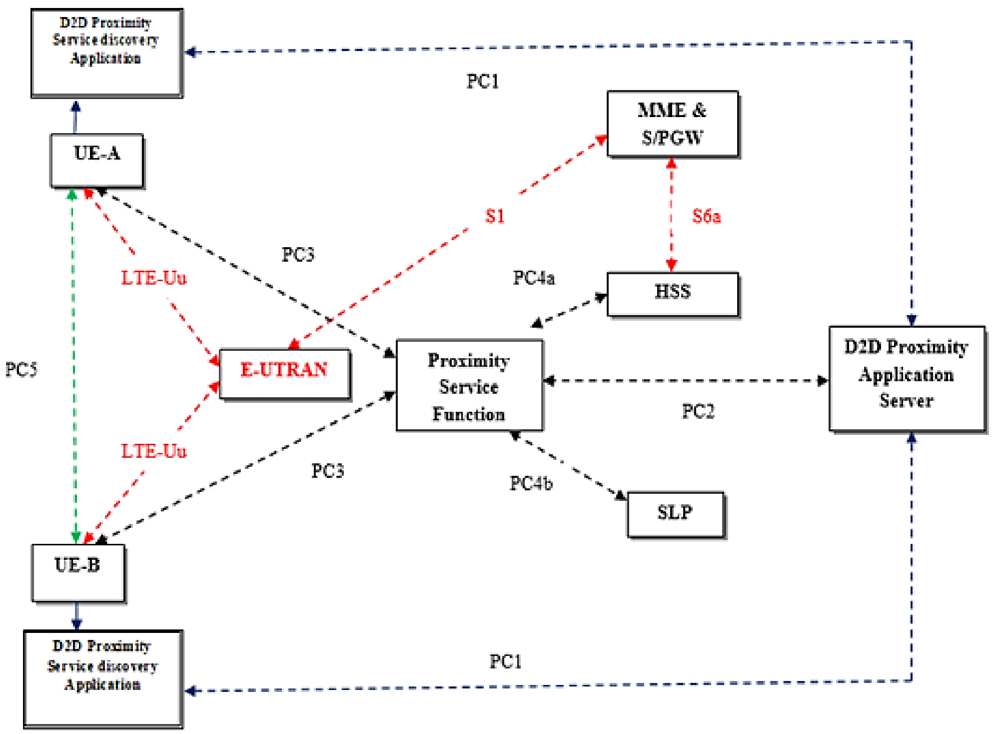

Fig.1. LTE-A architecture for supporting service discovery D2D communication.

Fig.1 shows Non-Roaming Reference Architecture mentioned in 3GPP release 12[6]. According to this architecture proximity direct discovery is possible if the UEs are under radio coverage of E-UTRAN. Direct discovery is the process in which a UE discovers nearby UE for D2D communication. All UEs must have D2D proximity service discovery application through which they will communicate with D2D proximity application server which is connected to Proximity service function block. There are two models of operation mentioned for direct discovery in 3GPP release 12. Model-A has been shown in Fig. 2 and Model-B has been illustrated in Fig.3.

Model-A ("I am here"): This model consist of announcing user equipment and monitoring user equipment. The announcing device send a messes to the neighbor devices that it can provides proximity services. A monitoring device immediately responds to the announcing device by means of acknowledge only if it wants to get that service. A proximity function is used to establish connection between announcing device and monitoring device [7].

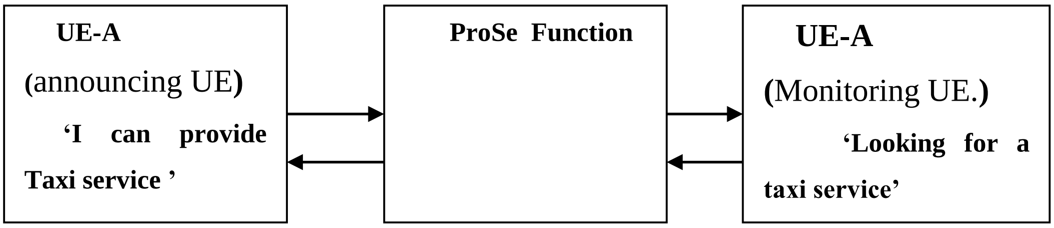

Fig. 2. Concept of model A

Model-B ("who is there?" / "are you there?"): This model consist of Discoverer device and Discoveree device. A discoverer device searches for proximity services whereas a Discoveree device reacts on a request provided by a discoverer device only if it is interested to provide a service. A proximity function is used to establish connection between Discoverer device and discovery device [7].

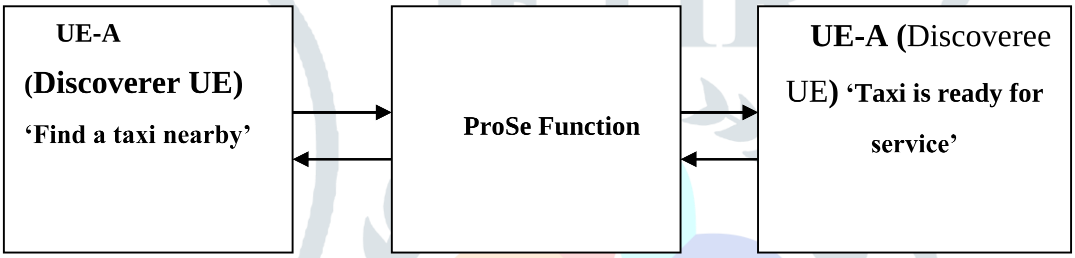

Fig. 3. Concept of Model B.

II. Proposed design of service discovery protocol

There are two possibility. (1) UEs that require service discovery are under radio coverage of E-UTRAN or UEs are out of radio coverage of E-UTRAN. For the second case we proposed an architecture where UEs that are out of coverage of E-UTRAN but may be under coverage of other networks like WLAN / Wi-Fi. Fig.4 shows proposed architecture.

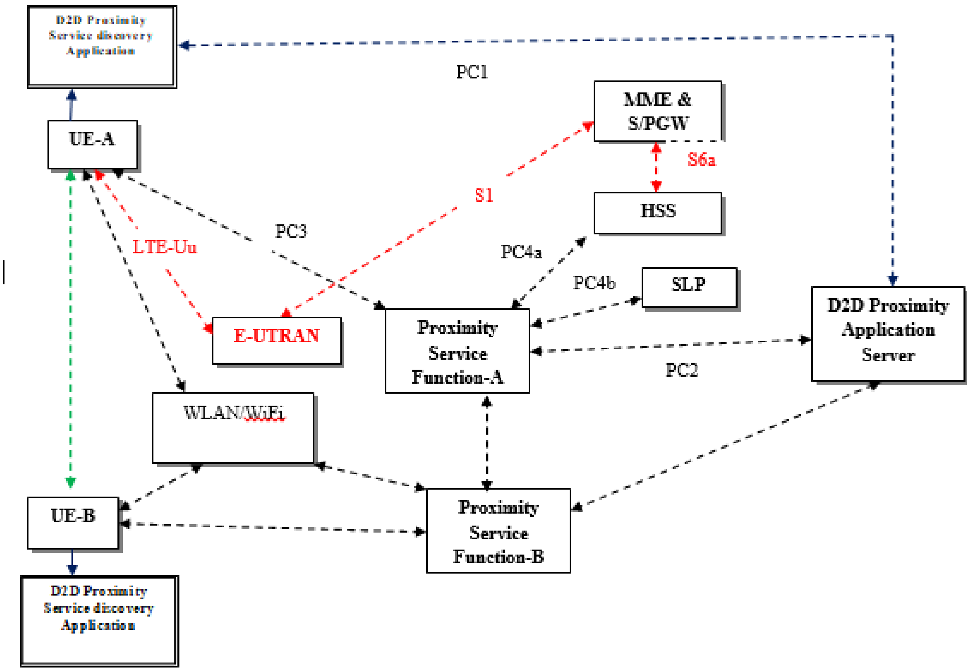

Fig.4. D2D service discovery with WLAN support in case of out of E-UTRAN coverage

UE-B is out of E-UTRAN radio coverage but under WLAN/Wifi coverage and UE-A is under E-UTRAN radio coverage. The steps for communication has been explain below

1) UE A transmits a signal which consist proximity service related request. This request is received by Proximity service Function-A. This request consists of several parameters like Application Layer User ID of UE-A and UE-B, Third party Application ID, EPC ProSe User ID, location of UE-A, Window parameter, WLAN Link Layer ID etc. This request is remain active for a specific duration of time window. Once the time is expired, the session need to be reinitiate by the corresponding user equipment.
2) Proximity service Function-A then send a MAP request to the D2D Proximity Application Server. This is a search request for checking the information of intended service and user permissions.
3) D2D Proximity Application Server send a MAP response to service Function-A after checking user authentication details of UE- B and UE-A. This response includes identification of proximity service function-B
4) ProSe Function A transmits a signal to ProSe Function B which consist a request message.
5) Proxy function-B retrieves subscriber B's record.
6) It checks the user profile of UE-B. Then it ensures permission for proximity request.
7) A request has been initiated for identification of location of UE-B. It is done by the proxy function using the WLAN ID.
8) Communication takes place between UE-A and UE-B.

III. Modeling and analysis reactive and proactive protocol

In this section we have presented calculation of control overhead and comparison of performance of reactive and proactive protocol. We have considered time frame based analysis. Let there are total T numbers of time frame available and a D2D request can be initiated by any UE randomly at any time frame. Reactive protocol uses following steps to initiate D2D request.

1) UE-E sends request to UE-R. This initiation request signal consist of service type, location address of UE-E and other related fields.
2) UE-R calculates various parameters like distance, probability of time delay, channel state information and optimal route. UE-R forwarded a signal to base station which contains all this information. Base station provides permission to UE-R to establish connection to UE-E.
3) Base station also checks profile and authenticity of UE-E. If it is authorized, then base station checks resource blocks are available or not. If RBs are available then it replies to the UE-R, otherwise it sends negative response to UE-R.
4) UE-R relays to UE-E response of base station.
5) UE-E transmits “D2D request” to contact corresponding services.

In proactive protocol, Base station will send notifications to all authenticated UEs (provided proximity area or geographical location) using multicast message for D2D communication. The process of D2D connection can be establish as per following-

1) Base station periodically transmit “Service advertisement message” to all user equipments available under its coverage.
2) UE-R transmits “Multicast D2D message” to group of devices. This message contain service type information and location information.
3) UE-E sends reply “D2D response” message to UE-R.
4) UE-R asks base station for D2D request permission by sending information about UE-E.
5) Base station initiate to provide resource block for establishment of D2D link.

Overhead calculation for reactive and proactive protocol: Let we consider there are total N numbers of UEs which generates M numbers of D2D request per time slot. Hence pdf of generated D2D request can be expressed as,

$$\rho = \frac{1}{\sigma\sqrt{2\pi}} \exp\left(-\frac{(M-\mu)^2}{2\sigma^2}\right) \qquad (1)$$

Here μ is the mean of Device to device request σ is the Standard deviation of a Gaussian random process. D2D request generation process has been considered as a Gaussian random process.

Protocol overhead for proactive is given by

$$(PO)_P = (2*(T-K) + K*(2+ (14*M)))/T \quad (2)$$

Protocol overhead for reactive is given by

$$(PO)_R = (K*15*M)/T \quad (3)$$

Where K is the time slot where Device to device request generated and T is the total number of time slots. Fig 5 shows D2D request vs control overhead plot for reactive and proactive protocol.it shows that reactive protocol is good for less no of D2D request whereas if number of D2D request increases (>5) then proactive protocol performs better than reactive.

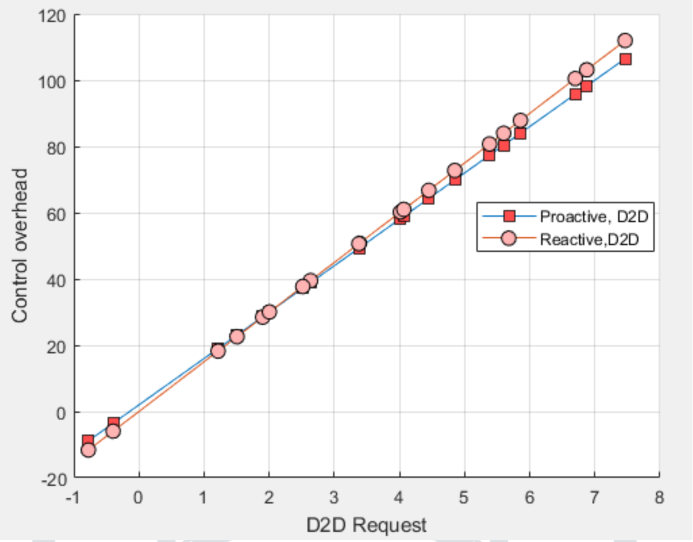

Fig.5. D2D request vs Control overhead plot for reactive and proactive protocol

IV. Conclusion

In this paper we have reported feasibility and reliability challenges of service discovery protocols for proximity based D2D communication in 5G NR architecture. Ultra-low delay and high reliability are the main concern in 5G NR. Reliability enhancement is possible only if outage probability of D2D link drastically reduces in presence of cellular links. 5G gNB assisted D2D proxy services for social and emergency application require further investigation because these applications are feasible only in low latency (packet drop rate $<10^{-5}$). Compatibility study of service discovery and D2D communication protocols used for unlicensed band communication (WLAN, Wi-Fi, NFC etc.) with licensed band D2D is a big challenge because it compromises quality of service guarantees.

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