

Performance Evaluation of Network-Assisted Device Discovery for LTE-Based Device to Device Communication System

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Abstract – Device-to-device communication (D2D Communication) enables direct communication between nearby devices. It is an innovative feature of next-generation cellular network. It facilitates the interoperability between critical public safety networks and present commercial networks based on LTE. Discovering Proximity Devices is a major challenge in realizing D2D Communication. In this paper we analyze how D2D Discovery can take the help of existing LTE infrastructure and increase its efficiency. We have also analyzed different worst case scenarios and in addition we have analyzed the best case as well as overall system throughput.

Index Terms – D2D Communication, Device Discovery, LTE

1. INTRODUCTION

Device-to-device communication (D2D communication) that enables direct communication between nearby mobiles is an exciting and innovative feature of next-generation cellular networks. This will facilitate the interoperability between critical public safety networks and present commercial networks based on e.g. LTE. In principle, exploiting direct communication between nearby mobile devices will enhance spectrum utilization, overall throughput, and energy efficiency, while enabling new peer-to-peer and location-based services and applications. D2D enabled LTE devices have the potential to become competitive for fallback public safety networks that also function when cellular networks are not available or fail. As number of nodes are increasing day by day, the traffic increase. Here there are two possibilities roughly for a communication between two distances based on proximity. If the Devices are very close to each other, it is both possible and better that they communicate directly without any external infrastructure such as Base station, etc., so that the offloading of Mainstream traffic can be done for regular Cellular Networks, which will in turn help the very far way devices to communicate without interruption efficiently. On the other hand if the devices are really far away, then we can use cellular Infrastructure for that.

Under an autonomous discovery mechanism, one party transmits a known synchronization or reference signal called a beacon, without any coordination via a randomized procedure[1]. Transmitting and searching without any coordination are typically energy and time consuming. So we

use the help of existing network for discovery process by coordinating time and frequency allocation for sending and receiving discovery channels. This results in efficient resource usage, interference coordination and communication mode selection based on link qualities [2].

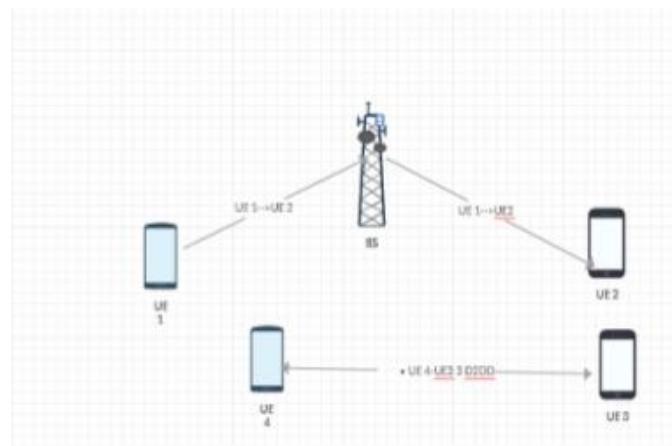


Figure 1: Example of Cellular and D2D Communication

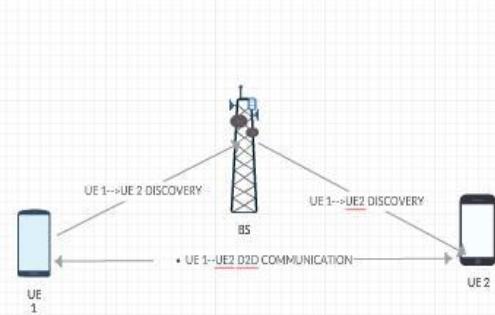


Figure 2: Example of Network assisted D2D Discovery

So we plan to use the network assisted discovery mechanism to increase efficiency of D2D Discovery process. The discovery method utilizes the resources allocated by the cellular network on nonuser basis. At any specific interval, a

group of users authorized to perform discovery contend to transmit their discover messages in a time-frequency multiplexed pool of network allocated Resources. We use a contention avoidance as well as contention resolution mechanism which consists of 3 simple rules[1]:

- Random selected search/Listen First States
- Randomly Selected Discoverable Interval per UE
- Randomly Selected frequency multiplexed discovery channels in each time-multiplexed discovery channels

The rest of the paper is organized as follows. Section 2 contains the model, Section 3 Contains Performance Metrics, Section 4 Contains Simulation Results, Section 5 Contains Conclusions and Section 6 Contains References.

2. MODEL

We take a System which consists of a set of devices and an enodeB (which is effectively the base Station coordinating the D2D Discovery process). D2D communication may occur in the same spectrum as the LTE Network (down-link or up-link or both) or in a different dedicated for D2D communication purposes. Underlying LTE Cellular system can be based on TDD or FDD.

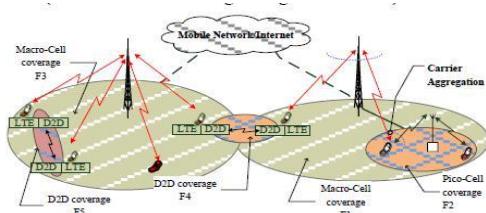


Figure 3: D2D System Model

A UE with the D2D Communication capability (D2D UE) is able to operate either in cellular mode, D2D mode or both at the same time. If the direct link quality deteriorates, the enodeB(s) can dynamically resume their communication in the cellular mode. The D2D Flowchart is given below

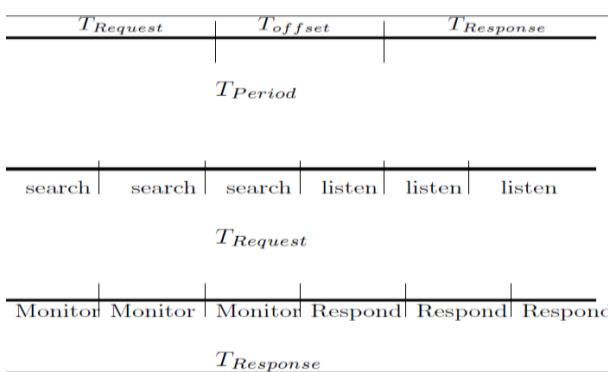


Figure 4: Tperiod, Trequest, Tresponse

3. PERFORMANCE METRICS

Worst case scenario of algorithm occurs when none of the users are discovered by others during a given discovery interval. This can happen in three ways:

- 1) X = No other user listens when each user transmits its discovery request message in the search state.
- 2) Y = When at least one user listens, all other users discovery request messages are collided at all discovery intervals (assuming that once collided they become non-resolvable).
- 3) Z = When all users discovery response messages are collided at all discovery response intervals.

N= Number of users participating in the discovery process.

T_{Req} = Number of discovery intervals per discovery period.

T_{Offset} =Discovery response offset

D_{max} = maximum discoverable interval.

D_{min} = minimum discoverable interval.

D_{UE} =discoverable interval for user equipment

K = number of frequency multiplexed channels per discovery interval.

Algorithm 1 Process

Require: N users are taken for communication

Require: T_{offset} , T_{dis} , T_{res} , $T_{req}(n*T_{dis})$, D_{min} , D_{max}

D_{UE} = RandomInteger(D_{min} ; D_{max})

$State_{UE}$ = Random(Search; Listen)

while(simulation<=1000)do

 while ($T_{req}!=0$) do

 if ($State_{UE}$ = Search)then

 goto Search

 end if

 if ($State_{UE}$ =Listen) then

 goto Listen

 end if

Search:

 While($D_{UE}!=0$)do

 UE selects the frequency multiplexed discovery channel and transmits its discovery request message

 goto Listen

end while

Listen:

while($D_{UE} \neq 0$)do

 It monitors all available frequency multiplexed discovery channels for request messages from other UEs

 end while

end while

while($T_{req} \neq 0$)do

 if (state_{UE} of the corresponding D_{UE} is search in

 T_{req}) then

 goto Monitor

 if (state_{UE} of the corresponding D_{UE} is Listen in T_{req}) then goto Response

 end if

 end if

Monitor:

while $D_{UE} \neq 0$ do

 UE monitors the discovery response channel associated with the discovery request channel selected for sending a discovery request message goto Response

 end while

Response:

While($D_{UE} \neq 0$)do

 if UE detects a discovery request signal during one or more previous listen states it sends response messages in the associated discovery response channels during the respond state then goto Monitor

 end if

 end while

end while

end while

The event ‘X’ occurs when all users’ search/listen patterns completely overlap. Therefore

$P(x) = P(\text{all UEs select same state AND all UEs select same discoverable interval})$

$= P(\text{all UEs select same state})XP(\text{all UEs select same discoverable interval})$

$$= \left(\frac{1}{2}\right)^{N-1} \left(\frac{1}{(D_{max} - D_{min} + 1)}\right)^{N-1}$$

$$= \left(\frac{1}{(D_{max} - D_{min} + 1)}\right)^{N-1}$$

The event ‘Y’ occurs when all users who select to search may select same frequency channel for transmission at all discovery intervals. Consider the first discovery interval. In this interval,

$$\begin{aligned} P(Y_1) &= P(M \text{ UEs select to transmit AND all those } \\ &\quad M \text{ UEs select same frequency channel}) \\ &\quad \text{for } 1 < M < N \text{ and } N > 2 \end{aligned}$$

$$\begin{aligned} &= P(M \text{ UEs select to transmit}) \times P(\text{all } \\ &\quad M \text{ UEs select same frequency channel}) \\ &\quad \text{for } 1 < M < N \text{ and } N > 2 \end{aligned}$$

$$= \sum_{M=2}^{N-1} \left(\binom{N}{M} \left(\frac{1}{2}\right)^N \right) \times \left(\frac{1}{k}\right)^{M-1} \text{ for } N > 2$$

It can be seen that the probability of all transmitting users’ signals collide with each other in any time interval is equal to above (Y_1). Thus

$$P(Y) = \left[\sum_{M=2}^{N-1} \left(\binom{N}{M} \left(\frac{1}{2}\right)^N \right) \times \left(\frac{1}{k}\right)^{M-1} \right]^A \text{ for } N > 2$$

The event ‘Z’ occurs at least one UEs discovery request signal is detected by more than one other UE and their discovery response signals collide with each other at all discovery intervals. We observed that the probability of occurrence of this event is negligibly small compared to that of other two events. Therefore, the probability of occurrence of the worst case scenario of the algorithm is approximated as,

$$P(\text{WorstCase}) \approx P(X) + P(Y)$$

$$\begin{aligned} &\approx \left(\frac{1}{(D_{max} - D_{min} + 1)}\right)^{N-1} \\ &+ \left[\sum_{M=2}^{N-1} \left(\binom{N}{M} \left(\frac{1}{2}\right)^N \right) \left(\frac{1}{k}\right)^{M-1} \right]^A \\ &\quad \text{for } N > 2 \end{aligned}$$

4. SIMULATION RESULTS

We checked the values of P(x) and P(y) and P(z) varying number of users from 2 to 20 keeping A and k Constant. We repeated this for many values of A ranging from A=2 to A=6

Parameter	Values
Frequency Channels	$k=2$
Minimum Discoverable Interval	$D_{min}=1$
Maximum Discoverable	$D_{max}=A$
Number of Simulations	1000

Table 1: Simulation Parameters

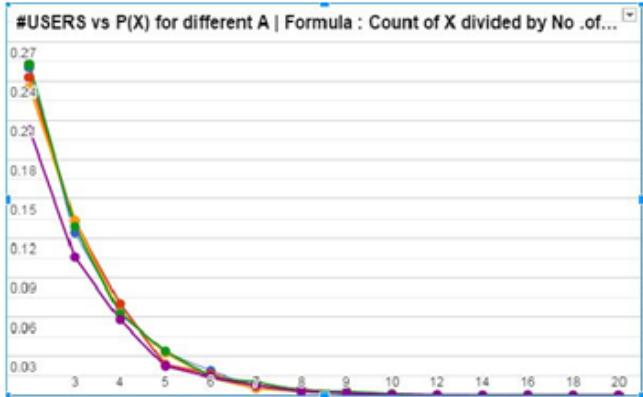


Fig 5: Users Vs $P(x)$

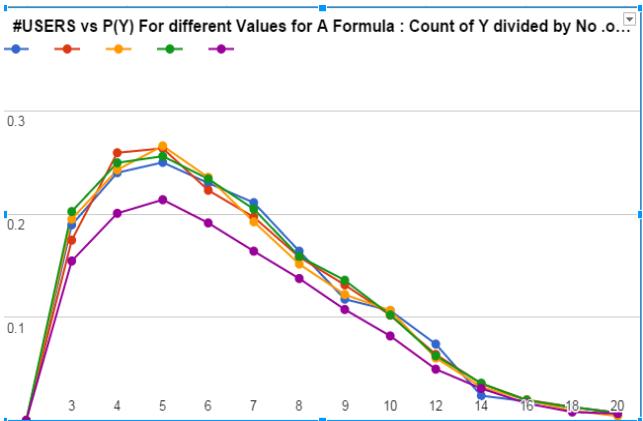


Fig 6: Users Vs $P(y)$

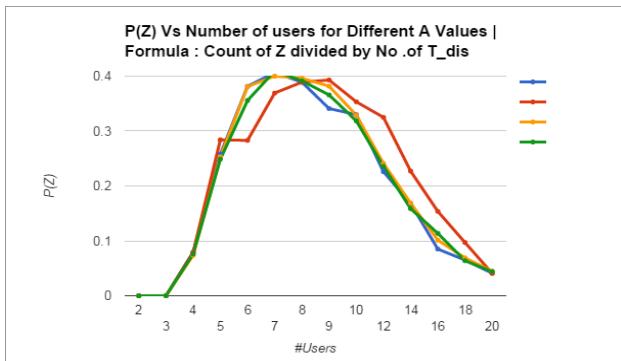


Fig 7: users Vs $P(z)$

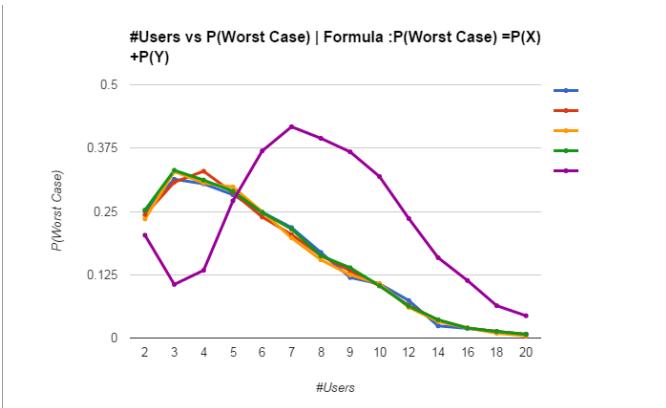


Figure 8: users Vs $P(x)+P(y)$

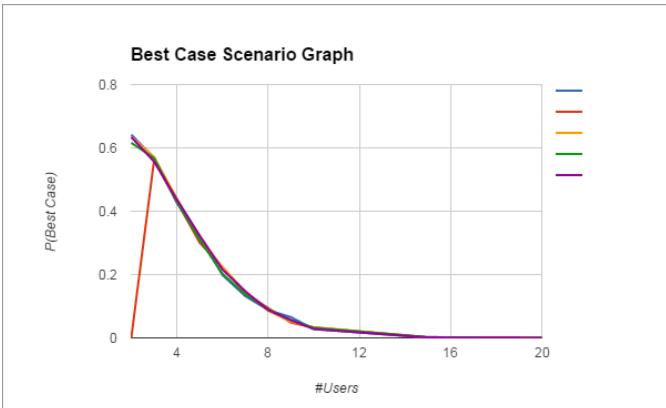


Figure 9: Users Vs $P(x)+ P(y)$

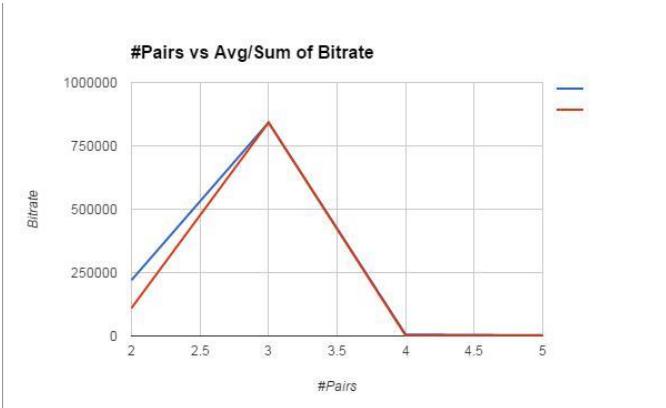


Figure 10: users Vs Throughput –System Average

5. CONCLUSION

This paper proposes a network assisted device discovery method for D2D communication in cellular networks by considering performance in to an account. In the proposed method a community of user equipment's is allowed to transmit discovery messages in time-frequency multiplexed channel. Race among the UEs are resolved by three-

dimensional random approach. This paper evaluated the performance of proposed method also. This performance evaluation includes worst case scenario.

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