Prioritization in D2D Communication

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***Abstract*—Many disasters and natural calamities are occurring these days, and their frequency is growing at an alarming rate. Many people perish in these disasters because they are unaware of the natural calamities until it is too late. As a result, it is critical to provide high-performance and accurate communications to first responders during such incidents in order to enhance their teamwork skills and knowledge of the immediate environment, as well as to enable them to quickly send and receive warnings on potentially hazardous circumstances or emergencies. As a result, D2D communication was implemented to speed up public safety communications. However, D2D communication is now used for a variety of other purposes. As a result, the base station must first determine the intent before allocating resources to each D2D pair, which takes time and thus slows down the communication process. So here we have come up with a novel idea that felicitates the public safety communications and the same we have implemented with the help of Network simulator 3. We have basically grouped all D2D users carrying out a public safety communication under a group and rest others into the other group using k -means algorithm. Therefore if a public safety communication is going on the eNB can easily come to know at the earliest and can give more reference to those communications by allotting best possible resources to carry out such communications.**

I. Introduction

1) What is NS-3-PSC ?

   i) NS-3 : NS-3 is a discrete Network Simulator designed specifically for educational and testing purposes. It comes with a number of useful tools for visualising simulations. It's a free software and an open source project. It has been made available for research and development to the general public. The network simulator NS-3 is the third edition. NS-3 aids in the implementation of a variety of real-world network protocols and supports both IP and non-IP networks. NS-3 is, in a nutshell, a boon to today's research and development.

   ii) PSC : PSC stands for Public Safety Communication,which involves sharing of critical information to other fellow people. It also includes providing of timely event details to resident and community members to ensure their safety. If there is some public safety communication in progress, the communication should take precedence over all other communications. They are the first responders. D2D communication was basically introduced to felicitate public safety communications.

2) What is D2D communication ?

   D2D communication is a modern technology that allows for direct communication between nearby devices without the need for the base station to be involved. It was first implemented in 4G and has since evolved into one of the pillars of 5G networks. It was originally designed for public safety application-based communication, but it is now used in almost every other sector. Unlike conventional communication, the eNB is not directly involved in the communication, i.e.the communication link is not established by the base stations. It only allocates the resources and hence felicitate the communication. D2D communication was introduced under proximity services under the 3rd Generation Partnership Project. It is also called as side link communication.
   The following are some examples of D2D communication techniques:

   - Bluetooth 5
   - WiFi Direct
   - LTE Direct

3) What is sharding ?

Sharding is a database management system concept that essentially means clustering, or grouping items together. The term ”shard” refers to a ”small part of a larger whole.” As a result, sharding is described as the division of a larger part into smaller parts.

4) What is SINR ?

SINR is basically Signal to Interference plus noise ratio. It is also sometimes called SNR which is Signal to Noise ratio. SINR is used to give theoretical upper bounds on channel capacity in wireless communication system. SINR is commonly used in wireless communication as a way to measure the quality of wireless connections. It has got more importance when it comes to wireless communication because in wireless communication signals are transmitted in all 360 degrees as there is no dedicated path. So lot of interferences happen between various signal leading to addition of noise. SINR basically gives the amount of unwanted interference and noise added to the signal.

5) What is RNTI ?

Radio Network Temporary Identifier (RNTI) is an acronym for Radio Network Temporary Identifier. It's a type of identification number, as the name suggests. Normally, we use a number to distinguish one thing from all those that are identical. In the context of LTE, this RNTI is used to distinguish one radio channel from another radio channel, as well as one user from another user.

6) What is RSRP?

RSRP is an acronym for Reference Signal Received Power. It's one of the most important indicators of signal strength and efficiency in modern LTE networks. It is a measurement of the received power level in an LTE cell network.

7) What is Throughput?

Throughput is the rate of successful message delivery over a communication channel. The data these messages belong to may be delivered over a physical or logical link, or it can pass through a certain network node. Throughput is usually measured in bits per second (bit/s or bps), and sometimes in data packets per second (p/s or pps) or data packets per time slot.

8) What is End to End Delay?

The time it takes for a packet to travel from source to destination through a network is referred to as end-to-end delay. It's a common concept in IP network monitoring, and it's different from round-trip time (RTT) in that it only measures one route from source to destination.

II. PROBLEM STATEMENT

Enb is referred to as a ”dumb system” because it is unable to continually review each request for resource allocation from UEs. As a result, regardless of the type of application, it allocates similar resources. As a result, a system that uses social media is given the same priority as a public safety device, which should not be the case. As a result of sharding/clustering devices based on application type, enb can easily distinguish between them and determine which shard the request originally comes from. As a result, the enb can easily assign resources as required.

III. OBJECTIVES

The objectives of this project are mentioned below:

- To group d2d devices based on their application
- Create clusters in each group using k means.
- Provide more resources to D2D users carrying out public safety communications .
- To calculate the SINR values of the UE devices in the newly created shards
- To calculate throughput and end to end delay for public safety shard and social media shard.

IV. METHODOLOGY

We used an open source project called NS3-PSC, which is primarily used for network simulation, to achieve the above goals. We designed this project using ltesl-in-convrg-comm-mode1.cc as the base code and we have built our code upon this file.

1) Sharding based on application type :

We have created classes for d2d devices (d2d user) and CU devices (cu user) . We've specified attributes like 'position ' , 'application type' and 'cluster id' for d2d devices (d2d user) and CU devices (cu user) so that we can cluster the d2d users based on the application type. The proposed sharding method can be broken down into three steps:

a) Differentiating d2d users based on application:

Using the rand() function, each d2d system

is assigned a random application type . We have used '1' for social media applications and '2' for public safety applications in this code. These d2d devices are then divided into two categories based on their application types-

(i) Social Media
(ii) Public Safety.

Pseudo code for grouping

```
for all d2d_devices
{
  if(d2d_devices.application_type ==
      1)
     add it to the Social Media
        group;
  if(d2d_devices.application_type ==
      2)
     add it to the Public safety
        group;
}
```

b) Clustering through k-means :

Then we run k-means on each group separately to get clusters/shards of d2d devices that belong to the same application class. The k-means algorithm generates k centers/centroids, i.e. k clusters, which are returned to the main function, where the information (cluster id) and the centres are stored. Here we have created 2 clusters in public safety group and one cluster in social media group. The pseudo code for the k-means algorithm is shown below

Pseudo code for k-means

```
create random centers;
do
{
   for all d2d_devices in a group
   {
      find the shortest center from
         the d2d device;
      assign cluster id for the
         d2d_device;
      update the centers;
   }
}until(current centers == previous
    centers)
return centers;
```

c) Assign each Cu to the nearest cluster :

One CU device is allocated to each cluster. The assigning method is based on distances, which means that the nearest CU devices are allocated to a specific cluster, and we've made sure that the same CU device isn't assigned to two clusters.

2) Resource Allocation :

Since d2d nodes carrying out public safety communications are first responders they should be given more resources than any others users. In order to accomplish this ,we have assigned 1o resources blocks to d2d nodes carrying out public safety communications which is double the number of Rbs allocated to other users. We have also increased the PRB number for them and at last we have also increased the the UE transmission power for the users carrying out public safety communications so as to increase the signal strength. Fig 2 shows resource allocation for d2d nodes carrying out public safety communications and Fig 1 shows resource allocation for d2d nodes carrying non critical communications.

```
Config::SetDefault ("ns3::RrSlFfMacScheduler::SlGrantSize", UintegerValue (5));
pfactory.SetControlPrbNum (10);
pfactory.SetControlPrbStart (0);
pfactory.SetControlPrbEnd (49);
Config::SetDefault ("ns3::LteUePhy::TxPower", DoubleValue (20.0));
```

Fig. 1. Resource Allocation for Social Media communications

```
Config::SetDefault ("ns3::RrSlFfMacScheduler::SlGrantSize", UintegerValue (10));
pfactory.SetControlPrbNum (24);
pfactory.SetControlPrbStart (0);
pfactory.SetControlPrbEnd (49);
Config::SetDefault ("ns3::LteUePhy::TxPower", DoubleValue (23.0));
```

Fig. 2. Resource Allocation for Public Media communications

3) Initiating the communication :

Assume there are N D2D pairs (D2DN) in a shard after the sharding process is complete, with N ranging from 1 to N. The D2D pairs begin communication at regular intervals, for example, the D2D1 pair begins data transfer at 2 seconds, the D2D2 pair at 3 seconds, the D2D3 pair at 4 seconds, and so on.

4) SINR :

SINR is basically Signal to Interference plus noise ratio. It is also sometimes called SNR which is Signal to Noise ratio. SINR is used to give theoretical upper bounds on channel capacity in wireless communication system. SINR is commonly used in wireless communication as a way to measure the quality of wireless connections. SINR is calculated as follows.

$$SINR = \frac{Signal\ Power}{Noise + Interference\ Power}$$

SINR values of d2d nodes in second shard of public safety group were determined and printed. The nodes SINR values are determined for the time period specified in the query. In order to calculate the SINR (Signal to Noise Ratio) We used the 'ReportCurrentCellRsrpSinr' function from LteUePhy, which is called right after the simulation ends. This calls the PhySnirTrace module, which takes SINR as one of its parameters. The function PhySnirTrace is defined just above the main function.

5) Throughput and end to end delay Calculations :

Throughput is the rate of successful message delivery over a communication channel. The data these messages belong to may be delivered over a physical or logical link, or it can pass through a certain network node.

$$Throughput = \frac{No\ of\ bytes\ received}{Time\ taken} \quad Kbps$$

End to end delay is amount of time taken by the packet to reach the destination node. If packet is sent at time T1 and if it reaches the destination node at time T2 then end to end delay is calculated as follows

$$End\ to\ End\ Delay = T2 - T1$$

To calculate the above two values , we generate 4 trace files corresponding to the 4 shards created. Two for public safety groups and two for social media groups. Then we use awk file to calculate throughput and end to end delay for all the shards with the help of trace files.

V. RESULTS AND ANALYSIS

When we run the project.cc file with the command "./waf –run scratch/D2D20 " , all of the newly formed D2D users will be allocated an application type, based on which two groups will be created, Then in each of the group formed 2 clusters will be created with the help of K means clustering algorithm. Finally one Cu is added to each of the shard created on the basis of nearest distance between the shard and the CU.

The code First outputs the basic details of all the d2d users as shown in fig 4 and 5. Then it outputs all the details of the shards created , showing which d2d users are present in which shard. Finally the code outputs the Sinr , Rnti and Rsrp values for all the d2d users in shard 2 of the public safety group in a well structured manner. Initially the function PhySnirTrace targets the first user in that shard and then increases the number of users to be target by 1 with each increasing second. Following is the format in which the values are printed.

```
Time : 2.5 d2dNode : UE0
Time : 3.5 d2dNode : UE0 , UE8
Time : 4.5 d2dNode : UE0, UE8 , UE12
Time : 5.5 d2dNode : UE0, UE8 , UE12 , UE18.
```

The code also generates 4 trace files corresponding to 4 shards created . Following are the trace files created

1) psc_shard1.tr
2) psc_shard2.tr
3) sm_shard1.tr
4) sm_shard2.tr

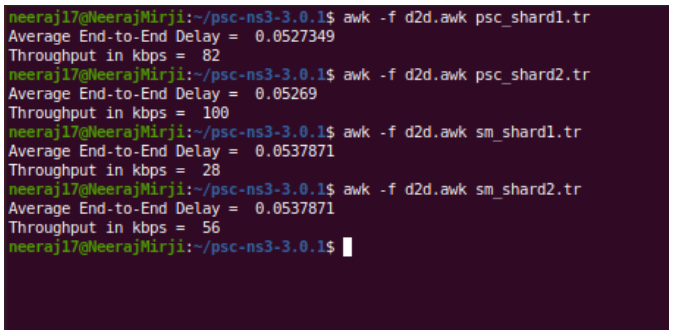

Fig. 3. End to End Delay And Throughput Calculation

The first two belong to the public safety group and the other two belong to social media groups. With the help of these trace files and awk file , Throughput and end to end delay calculations are carried out. Fig 3 shows the throughput and end to end delay for each of the shards.

From the above Fig it can be seen that throughput for public safety shards is more as compared to social media shards and end to end delay for public safety shards is less than that of social media shards. Hence all the d2d users who are carrying out public safety communications are given more priority than any other users.

VI. CONCLUSION

The submitted NS3 code successfully groups all available d2d users on the type of communications they are carrying

```
 D2D Pair Details
************************************************************
Node Id : 0
Application Type : 2
Cluster Id : 1

Node Id : 1
Application Type : 1
Cluster Id : 1

Node Id : 2
Application Type : 2
Cluster Id : 0

Node Id : 3
Application Type : 2
Cluster Id : 0

Node Id : 4
Application Type : 2
Cluster Id : 1

Node Id : 5
Application Type : 2
Cluster Id : 0

Node Id : 6
Application Type : 2
Cluster Id : 1

Node Id : 7
Application Type : 1
Cluster Id : 0

Node Id : 8
Application Type : 1
Cluster Id : 1

Node Id : 9
Application Type : 2
Cluster Id : 1
```

Fig. 4. D2D Pair Details

```
 CU Details
************************************************************
CU : 1
Application Type : 2
Cluster Id : 1

CU : 2
Application Type : 2
Cluster Id : 0

CU : 3
Application Type : 1
Cluster Id : 1

CU : 4
Application Type : 1
Cluster Id : 0
```

Fig. 5. CU details

```
                        SOCIAL_MEDIA

Shard 1 = {
                UE14  , IP_Address : 7.0.0.20
                UE15  , IP_Address : 7.0.0.21
                CU4  , IP_Address : 7.0.0.5
          }


Shard 2 = {
                UE2  , IP_Address : 7.0.0.8
                UE3  , IP_Address : 7.0.0.9
                UE16  , IP_Address : 7.0.0.22
                UE17  , IP_Address : 7.0.0.23
                CU3  , IP_Address : 7.0.0.4
          }
```

Fig. 6. Social Media Shard

```
                        PUBLIC_SAFETY

Shard 1 = {
                UE4  , IP_Address : 7.0.0.10
                UE5  , IP_Address : 7.0.0.11
                UE6  , IP_Address : 7.0.0.12
                UE7  , IP_Address : 7.0.0.13
                UE10  , IP_Address : 7.0.0.16
                UE11  , IP_Address : 7.0.0.17
                CU2  , IP_Address : 7.0.0.3
          }


Shard 2 = {
                UE0  , IP_Address : 7.0.0.6
                UE1  , IP_Address : 7.0.0.7
                UE8  , IP_Address : 7.0.0.14
                UE9  , IP_Address : 7.0.0.15
                UE12  , IP_Address : 7.0.0.18
                UE13  , IP_Address : 7.0.0.19
                UE18  , IP_Address : 7.0.0.24
                UE19  , IP_Address : 7.0.0.25
                CU1  , IP_Address : 7.0.0.2
           }
```

Fig. 7. Public Safety Shard

out i.e on the basis of application , and small clusters are formed in each group. On the basis of cluster id, eNB can now conveniently distribute resources to all d2d users.

If a D2D user is carrying out public safety communications, enb will quickly learn about it with the help of application id and cluster id, and they will be given higher priority than other users.

This saves a lot of time and makes the communication process much more effective, as well as serves the purpose of d2d communication.

The submitted code also calculates the signal to noise plus interference ratio for all d2d users that receive packets, indicating the amount of unwanted interference and noise added to the signal during the transmission phase and thus helps in knowing the upper bounds on channel capacity. The code also generates 4 trace files corresponding to 4 shards created . Two of which belongs to public safety group and the other two belong to social media group. With the help of these trace files and awk file analysis of Throughput and end to end delay can be done.

INDIVIDUAL CONTRIBUTION

- **Gaurav Singh** - Code, Report
- **Neeraj Mirji** - Code, Idea, Report
- **Kiran Kumar J M** - Code, Report

```
   SINR values of Shard 2 public saftey

UE0 belonging to D2D1
Time : 2.50021
RNTI : 2                rsrp : 2.89893e-10              SINR : 611149

UE0 belonging to D2D1
Time : 3.50021
RNTI : 2                rsrp : 2.89893e-10              SINR : 611149

UE8 belonging to D2D2
Time : 3.50021
RNTI : 41                rsrp : 2.98329e-11              SINR : 62893.3

UE0 belonging to D2D1
Time : 4.50021
RNTI : 2                rsrp : 2.89893e-10              SINR : 611149

UE8 belonging to D2D2
Time : 4.50021
RNTI : 41                rsrp : 2.98329e-11              SINR : 62893.3

UE12 belonging to D2D3
Time : 4.50021
RNTI : 6                rsrp : 5.63876e-12              SINR : 11887.6

UE0 belonging to D2D1
Time : 5.50021
RNTI : 2                rsrp : 2.89893e-10              SINR : 611149

UE8 belonging to D2D2
Time : 5.50021
RNTI : 41                rsrp : 2.98329e-11              SINR : 62893.3

UE12 belonging to D2D3
Time : 5.50021
RNTI : 6                rsrp : 5.63876e-12              SINR : 11887.6

UE18 belonging to D2D4
Time : 5.50021
RNTI : 27                rsrp : 5.16436e-11              SINR : 108874
```

Fig. 8. SINR Values of Public Safety Shard

REFERENCES

- lte-sl-in-convrg-comm-mode1.cc
- PSC-NS3 Documentation
- NSNAM LTE Documentation
- Flow Monitor Documentation