SELF-ORGANIZING NETWORKS PROSPECTS FOR GROUP SCHEDULING FOR DISASTER RELIEF AND PUBLIC SAFETY COMMUNICATIONS IN CELLULAR NETWORKS

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ABSTRACT

The demand for cellular communications is anticipated to continue its hasty growth in the forthcoming future, triggered by new bandwidth hungry applications such as voice over LTE, high-definition video streaming, and multimedia file sharing in mobile phones. This has placed enormous pressure on cellular communications in terms of demand for Quality of Service (QoS), capacity, and resource management. Henceforth, the apposite utilization of obtainable spectrum is required. Public Safety (PS) organizations' capability to exchange information is crucial to meliorate the coordination in emergency junctures. Recent catastrophes have underlined the need to enhance broadband and seamless connectivity to the PS organizations. This thesis outlines the governing issues necessitated in this, and also additional requirements of the network are addressed regardless of dynamic channel conditions and locations. In this thesis, subscribers are divided into groups viz., PS groups and regular subscriber groups. A new scheme, beyond the type of services being used by subscribers, priorities and fairness, is developed. In order to abridge operational costs and efforts, SONs (Self Organizing Networks) are implemented in this thesis and the prospects have been discussed.

Additionally, Group Scheduling is implemented to achieve better performance for PS and regular subscribers groups. An advanced scheduling algorithm for group scheduling is developed which provides better QoS for multi-services and a better trade-off between Quality of Service and radio resource management. This scheduling algorithm provides a better balance between multi-QoS purveying to support mixes of sensitive traffic and best effort traffic. This phenomenon is used to choose the best subscriber and the group. Several metrics have been devised and are used for this purpose. Extensive simulation results are shown for both the conditions viz., normal and emergency conditions.

APPROVAL PAGE

The faculty listed below, appointed by the Dean of the School of Computing and Engineering have examined a thesis titled "Self-Organizing Networks Prospects for Group Scheduling for Disaster Relief and Public Safety Communications in Cellular Networks", presented by Venkatasantosha Bhargava Thondapu, candidate for the master of Electrical Engineering degree, and certify that in their opinion it is worthy of acceptance.

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CHAPTER 1

INTRODUCTION

The cellular phone has become a necessity for human lives because of its wide and varied applications, and it is the device used in foremost places at times of emergency situations and extreme cases. Rescue operations can provide welfare from prevalence of communications during and just after the catastrophes like hurricanes, cyclones and earthquakes. At present, PS Organizations rely on their own systems and insufficient spectrum, which merely makes it impossible to gratify the requirements at the time of disasters. Also, the above factors don't at all contribute to taking advantage of present advances in Wireless Communications Technology. As well, there is no proper reliable technology which is senses the environment and acts according to it. So, PS Organizations and regular subscribers require an intelligent communications system which is smart enough to handle the abrupt changes in the environment and act according to it.

In order to increase the effective coordination, interoperability between PS Groups and regular subscribers is needed, along with the ability to sense varying channel conditions. SONs in cellular technology takes a vital role in achieving this coordination.

1.1 Motivation of the Project

Unfortunate disasters like Cyclone Hudhud in India and Hurricane Katrina in the U.S. emphasized that present communication systems or cellular technologies available for PS Organizations and regular subscribers are not capable enough to handle the large operations for disasters. Predominant persisting issues like the dynamic nature of the channel, resource management for PS groups and regular subscribers, the need of Intelligent and smart communication systems. Hence, they require proper solutions to dispose these issues.

1.2 Objective of the Project

This project provides a framework and few initial solutions to the problem of radio resource management for PS groups and regular subscribers. They both need equal levels of performance furnished by current technologies; merging them to access the same technology could be a viable alternative. Group scheduling can be carried out where multi-QoS requirements could be satisfied at both group level and user level.

Fairness and Efficiency are two crucial parameters that are to be accomplished by any network. The main objective of this project is to equalize two parameters while assuring user and group requirements for PS Groups and regular subscribers for normal conditions and in emergency conditions. Several functions are developed, simulated, and compared. It is also ensured that the scheduling scheme be valid under any conditions Extensive simulation results are shown for both the conditions viz., normal and emergency conditions. Also, the concept of implementing SON in cellular networks is discussed and demonstrated how SON can make the whole objective achievable.

CHAPTER 2

BACKGROUND

2.1 Evolution of Cellular Technologies

The evolution of Wireless Cellular Technology has been categorized into 'G – Generations'. The first generation (1G) accomplished basic mobile voice. In order to increase the capacity and efficiency, a second generation (2G) was developed, which instituted capacity, mobility and coverage. 2G is also termed GSM (Global Systems for Mobile Communications).

This was followed by the 2.5G (General Packet Radio Service) with increased speeds. Packet switched domain was also implemented. Further, 2.75G (Enhanced Data Rate for GSM Evolution) was introduced with meliorated data speeds.

Later, 3G (WCDMA), which has pursued data with higher speeds, led to a veritably "mobile broadband" experience. Many sophisticated features like video streaming, video conferencing, etc. are rendered by this technology.

Furthermore, Fourth generation (4G) will provide access to a wide range of services, including High Definition Video Streaming, and real time and interactive gaming in accordance with service requirements in the multiuser environment.

Two 4G candidate systems are commercially deployed: Mobile WiMAX and LTE. WiMAX was deployed in 2008 and in 2010 4G LTE has been deployed with peak data transfer rate up to 100 Mbps. Through the cellular network evolution, data rate and data related services are given more importance. Further, the features and architectures of LTE are described below.

2.2 Long Term Evolution (LTE)

In contrast to the legacy systems, LTE has been contrived to affirm exclusively packet-switched services. It aims to provide seamless IP (Internet Protocol) connectivity between user and the packet data network (PDN), during mobility. The main features of LTE are as follows

- Peak download data rates up to 300 Mbps and upload speed at 75 Mbps. (using 20 MHz band with 4x4 MIMO.)
- Ameliorated mobility illustrated by support for UEs moving at up to 220 mph or 310 mph.[1]
- Low latencies for data transfer.
- In order to conserve power OFDMA scheme for downlink and SC-FDMA scheme for uplink.
- Increased spectrum flexibility.
- Simplified and flat architecture (no centralized controller)

2.3 QoS (Quality of Service)

QoS is used to depict the user's overall experience while in the network. QoS necessitates a wide range of protocols, architectures and technologies. A network typically handles many service requests and services simultaneously from many users. The LTE acquaints different traffic classes and few QoS inputs to define the traffic characteristics and the classes of traffic. Differentiation of QoS is used to increase network efficiency during heavy load conditions.

The "Bearer" is considered a central element of the QoS concept. It is a data packet flow established between the nodes UE and PDN Gateway. LTE supports two types of bearers.

- Guaranteed Bit Rate (GBR): GBR bearers are given higher data rates when resources are available in network, otherwise they are given guaranteed minimum bit rate.
- Non-Guaranteed Bit Rate (NGBR): NGBR bearers are not guaranteed the minimum bit rate. The bit rate depends on eNodeB and load conditions in the cell.

LTE specifies nine standardized QCI (Quality Channel Indicator) values with standardized characteristics, which are pre-configured at the network nodes. The following table illustrates the standard QCI values.

QCI	Resource type	Priority	Packet delay budget	Packet error loss rate	Example services
1	GBR	2	100 ms	10^{-2}	Conversational voice
2		4	150 ms	10^{-3}	Conversational video (live streaming)
3		3	50 ms	10^{-3}	Real time gaming
4		5	300 ms	10^{-6}	Non-conversational video (buffered streaming)
5	Non-GBR	1	100 ms	10^{-3}	IMS signaling
6		6	300 ms	10^{-6}	Video (buffered streaming) TCP-based (e.g., www, e-mail, chat, ftp, p2p file sharing, progressive video, etc.)
7		7	100 ms	10^{-6}	Voice, Video (live streaming), Interactive gaming
8		8	300ms	10^{-3}	Video (buffered streaming) TCP-based (e.g., www, e-mail, chat, ftp, p2p file sharing, progressive video, etc.)
9		9		10^{-6}	

Fig. 1: Standard QCI Values [8]

2.4 OFDMA (Orthogonal Frequency Division Multiple Access)

In the present scenario, proper spectrum utilization is gaining importance in order to maximize the efficiency. Capacity is also fueled by new bandwidth hungry applications. Hence, the cellular technology is in need of a new radio access scheme which should be proficient in spectrum utilization and should achieve higher data rates with minified interference. OFDMA is a scheme which can eradicate the above issues and can achieve more beneficial results than any other schemes for maximizing capacity and efficiency. The advantages of OFDMA over FDMA/TDMA/CDMA are the ability to take advantage of the selective channel frequency, scalability and orthogonality. OFDMA with MIMO furnishes superior quality of service. Orthogonal Frequency Division Multiplexing (OFDM) is a multiplexing scheme which subdivides the available bandwidth into multiple orthogonal frequency sub-carriers.

OFDM is an excellent choice as a multiplexing scheme for an LTE downlink network. In OFDMA, users are allocated a specific number of subcarriers. The number of subcarriers is dependent upon the bandwidth. As per LTE specifications, these subcarriers are advertised as PRBs (Physical Resource Blocks) and they have both time and frequency dimensions. Allocation of PRBs is handled by a proper scheduling scheme at eNodeB.

2.5 Fading

In wireless communications, fading is defined as the attenuation of a signal over a propagation medium. The fading may vary with frequency, time and position. Fading is often referred to as a random process. The signal transmitted from the eNodeB chooses different paths to travel and experiences reflection, diffraction and scattering as it travels to the User equipment.

Fading is mainly classified into:

1. Large Scale Fading.
2. Small Scale Fading.

In large scale fading, signal attenuation occurs over large distances. In this project, the Okamura-Hata model is used for calculating large scale fading. This model is used especially in rural areas. The coverage frequency ranges from 150MHz to 1.5GHz. This model can forecast the total path loss of wireless cellular communication.

The following is the formula used to calculate the path loss using the Okamura-Hata model:

$$L_p = 69.55+26.16*log\,(F_c)-13.82*log(H_b)-a(H_m)+(44.96.55*log(H_b))*log(d) \quad (1)$$

Where

$$a = (1.1*log\,(F_c)-0.7)*H_m-1.56*log\,(F_c)-0.8 \quad (2)$$

L_p is the Path loss in dB

F_c is the frequency in MHz

H_b is the height of the base station in meters (m)

H_m is the height of the mobile station in meters (m)

d is the distance between the base station and the mobile station in kilometers (km).

In small scale fading, signal attenuation occurs over small distances. In this project, Rayleigh fading is used to calculate small scale fading. This is best in urban areas, since there is no predominant line of sight propagation between eNodeB and user equipment. The radio signal is reflected, scattered and diffracted because of obstacles like buildings, trees etc.

2.6 Scheduling

"Scheduling plays an important role on how to distribute radio resources among a number of users taking into account channel conditions and QoS requirements" [2]. Scheduling schemes are precisely designed to maintain fairness among users. Some are designed for maximizing the throughput and increase spectral efficiency, and some are designed to maintain a trade-off between fairness and spectral efficiency.

Scheduling schemes can be categorized into two types:

1. Channel Aware Scheduling Schemes

   Channel Aware Scheduling schemes take the channel conditions into account and schedule the users according to it. Channel conditions consider the effects of channel fading. The following are the examples of channel aware scheduling schemes:

   Proportional Fairness and Maximum Carrier to Interference Ratio.

2. Channel Unaware Scheduling Schemes

   These schemes don't at all consider the channel conditions for scheduling. They are scheduled by few metric values which don't consider the effects of fading and multipath. The following is an example of the channel unaware scheduling scheme:

   Round Robin.

In coming sections these schemes are briefly discussed and were implemented in this project.

2.7 Self-Organizing Networks (SON)

The demand for cellular communications is anticipated to continue its hasty growth in the forthcoming future, triggered by new bandwidth hungry applications such as VoLTE, High Definition Video Streaming and multimedia file sharing in Mobile phones. This demand has put an enormous pressure on cellular communications networks in terms of demand for Quality of Service (QoS), capacity and resource management. This problem is further intensified by considering financial aspects from the operator's point of view. Generally the relation between QoS and capacity is proportional to the cost of capital expenditure (CAPEX) and operating expenditure (OPEX). Since subscribers may be loath to pay more for better services, minimizing OPEX and CAPEX will aid in making the business commercially viable. On the other hand, providing improved QoS and capacity is also a critical consideration for today's operators. It is therefore necessary to provide a trade-off between improved services and the preservation of healthy profits. SON in cellular network could be a sustainable solution.

The other driving factors which are motivating SON to be implemented in cellular networks are as follows:

- The unpredictable nature of channel conditions result in unachievable optimal efficiency and capacity of the wireless network. The legacy networks lack tractability to adapt intelligently to dynamic channel conditions.
- The increasing deployment of femtocells, picocells and relay nodes to build the systems makes them too large for regular operation. The advent of femtocells which are deployed with plug and play fashion especially causes huge interference by degrading its neighboring cell's performance. Hence, SON should be deployed to mitigate this issue.
- It is probable that in the future, as the complexity of cellular systems increases, human errors will also increase which will result in longer time for refurbishment and recovery.

In short, it is clear from the above factors that SON could be a feasible way to accomplish optimal capacity and efficiency.

As inferred in [3], SON can be defined as "*an adaptive and autonomous functionality in a system is said to be self-organizing if it is scalable, stable and agile enough to maintain its desired objective(s) in the face of all potential dynamics in its operating environment*."

The considerations and prospects of SON in this project are discussed in later sections.

2.8 Public Safety Communications

The Public Safety communication system is a wireless communications system employed by emergency service and disaster relief organizations like military, fire, police, medical etc. to aid people during emergency situations.

The spectrum allocation for public safety applications has always been an important topic since the beginning of wireless communication. Federal legislation in 1912, 1927, and 1934 established rules across the United States by which local, county, state and regional public safety organizations have built, maintained and updated their individual communications systems [4].

Public Safety and Homeland Security Bureau of the FCC has defined a few requirements for public safety communications such as Operability, Interoperability, Reliability, Resiliency, Redundancy, Scalability, Security, Efficiency and Interdependence.

This project merges the PS spectrum and makes them accessible for regular technologies. "In an envisioned future, public safety communications use the same technologies as the consumer market, allowing cost reductions and improved data service capabilities." [5] The project also addresses the lack of interoperability between emergency organizations. "The lack of interoperability between emergency response departments were not fully appreciated until the recent crisis highlighted the importance of coordinated operations on a broad scale." [6].

CHAPTER 3

OUR WORK

3.1 Group Scheduling

This project provides new methods for radio scheduling of public safety and subscriber groups. A mechanism called Group Scheduling is being used. Group scheduling is channel aware downlink radio scheduling for maximizing a network's capacity and utilizing the spectrum efficiently. The use of associating public safety groups and subscriber groups together for radio scheduling is implemented. The group scheduling scheme in this project has less complexity making it appropriate for execution in practical systems. During emergency situations there is a reduction in system capacity and increase in traffic demand.

In this project, we consider the multi-cell scenario where there are 20 subscribers belonging to 5 groups namely fire, police, medical, military and regular users. The groups are randomly distributed among three cells. We implement, multiple applications that may be used by a user at any time, each one having different quality of service requirements. For example a user from Fire group may use video call and on the other hand at the same time the user from regular users may use FTP file download or browse any web page. Video call has more strict requirements for QoS in terms of delay than FTP and web browsing.

We broadly classified users into two categories based on the QoS they provide.

- Guaranteed Bit Rate (GBR): GBR bearers are given higher data rates when resources are available in network, otherwise they are given the guaranteed minimum bit rate.
- Non-Guaranteed Bit Rate (NGBR): NGBR bearers are not guaranteed to get minimum bit rate. It completely depends on eNodeB and load conditions in the cell.

Our scheduler ensures the necessary QoS for a user. Each user has been associated with a QCI (QoS Class Indicator). Each QCI is characterized by priority. The following table provides example of mapping of the different application types to QCI.

Table 1: QCI values assumed for this project

QCI	Resource Type	Packet Delay Budget (msec)	Applications	Priority	Weight
1	GBR	100	Conversational Audio	1	10
2		150	Conversational Video (HD)	2	9
3		300	Video / Screen Sharing	3	8
4	NGBR	100	Buffered Video	4	4
5		300	FTP	5	3
6		300	Web Browsing	6	1

Also, we considered that the user uses these services for a fixed number of slots or a fixed time. Scheduling decisions are made between the groups and use two levels of decisions.

1. Decision to choose a group.
2. Decision to choose a user inside the group.

These decisions are coordinately made between three enodeBs to choose a group and a user. Different scheduling schemes are employed and compared in the Group scheduling mechanism to perform the group decisions. Maximum Carrier/ Interference Ratio, Proportional Fairness and a new metric named the TMF metric which provides a tradeoff between Maximum Carrier/ Interference Ratio, Proportional Fairness and Applications or services being used by user.

Max C/I (maximum carrier-to-interference ratio) chooses the users with best channel conditions that are usually near to eNodeB, hence assuring throughput maximization. It compares the signal strength of the users and choses the one which has maximum values. Unfortunately, the users with bad channel conditions i.e., which are far from the enodeB have less chances and sometimes no chance to be chosen. Thus, Max C/I is not suitable for this case as it is unfair to the users.

Proportional Fairness (PF) scheduling algorithm chooses a user with the best PF metric. PF metric is defined as the ratio of instantaneous effective channel rate divided by its achieved average channel rate, which is formulated below.

$$PF = \frac{r_i}{\overline{r_i}}$$

Where $\overline{r_i}$ = average channel rate,

r_i= instantaneous channel rate,

The PF scheduling algorithm achieves high throughput while ensuring fairness among all the users.

A new metric named TMF metric is proposed in this project which is a function of type of service used, channel conditions and fairness. The following is the formula for the TMF metric.

$$TMF = W * r_i * \frac{r_i}{\overline{r_i}}$$

Where $\overline{r_i}$ = average channel rate,

r_i= instantaneous channel rate,

W = Weight of the Service.

This metric carries all the qualities for tradeoff between throughputs and maintains fairness between groups and the users. The results at the end also show this method to be viable and the best alternate to the Max C/I Metric and PF Metric.

3.2 QoS Requirements

Multi-QOS requirements and fairness are crucial parameters for every group regardless of their channel conditions and demands from other groups. Several groups in a cell region have different requirements. Also, group capacity is protected so that one group's behavior cannot affect the other.

In this project, the throughput requirements are met in such a way that for the available resources the GBR users are guaranteed to get their minimum throughput. Or they are satisfied with minimum service requirements irrespective of channel conditions. After serving minimum throughput to GBR users, if any resources are sufficiently available then the scheduler provides minimum throughput to NGBR users. Even if NGBR is served enough, the additional resources are used to provide maximum throughput to the GBR users depending on their service requirements.

The following table provides minimum and maximum throughput requirements for the services being used by users.

Table 2: Types of Services and Bandwidth Requirements

Service Type	Minimum Throughput (kbps)	Maximum Throughput(kbps)
Conversational Audio	30	100
Conversational Video (HD)	1200	1500
Video / Screen Sharing	512	2000
Buffered Video	400	500
FTP	128	300
Web Browsing	128	300

In this project, we consider OFDMA scheme for downlink radio scheduling of the users. We are considering that each enodeB has 20 resource blocks. The scheduler dynamically allocates these RB's to the users depending on the service used. Its main objective is to provide a minimum guaranteed throughput to the

GBR users either by providing its RB's or borrowing RB's from another enodeB to satisfy the purpose. SON is the only viable way to achieve the above.

3.3 Emergency Situation

Reliable communication is very important during emergency situations. The scheduler is designed in such a way that when 911 is dialed by 80% of regular subscribers, the network switches to the emergency situation and acts according to it. In this condition all the users are treated equally. Their weights get equal priority irrespective of the service used. There will be no dissection of GBR and NGBR users in the network the users and groups are prioritized by metric values.

All these schemes are implemented so that guaranteed and protected performance in commercial systems is provided to groups, along with prioritization between groups.

CHAPTER 4

MATLAB CODE IMPLEMENTATION

4.1 Introduction to MATLAB

MATLAB has been used as the programming tool to write and simulate the code for this project. MATLAB (also known as matrix laboratory) is a programming tool which has been developed by Math works. MATLAB is widely used in academic and research projects. MATLAB has hundreds of inbuilt functions which can be used to develop codes and also to plot the data. MATLAB is a user friendly tool which is the main reason for using it for this project.

4.2 Assumptions

Some assumptions are made for this project. They are listed below:

- users have traffic inflow at all times and change their services for every 5000 time slots
- time domain and frequency domain scheduling is only limited to downlink
- this simulation model does not include the effect of shadowing
- the fading model used in this project is more suited for suburban areas
- the distances between the user and eNodeBs was chosen at random, but then has remained the same for all the simulations to have consistency across all the results

The following are presumed for SON in this project:

- The network dynamically adapts to the changes in the network.
- EnodeB is self-established and has automatic neighbor relation management enabled in it.
- The overlapping coverage scenario is considered in optimization of load balancing and assumed that EnodeB effectively handles it.
- E-UTRAN Coverage holes, without any other radio coverage scenario, is considered in capacity and coverage optimization. It is assumed that EnodeB can optimize them.
- Also, we consider that handover parameter optimization has been achieved for detecting and mitigating handovers that are too late, too early, or to the wrong cell.

4.3 Code Description

Below is the description of the code implemented for this project:

- A total number of 20 users are divided into 5 groups.

  Each group has the same number of users for ideal conditions. Start index of each group is noted.

```
startindex=[1 5 9 13 17 21];
```

For practical conditionsn each group has a different number of users.

- For results with practical conditions, all the users are placed at certain distance (in km) from three eNodeBs in such way that all users experience overlapping coverage. For this we plotted the users and three eNodeBs in a rectangular coordinate system and calculated the distances of a user with respect to three eNodeBs.

```
% Location of Mobiles and Base Stations according to Layout.
% Mobile Location X Coordinate = MX.
MX = [-2.5 0 -1.5 0.5 2 1.5 0.5 -0.5 -1 -0.5 -2 -0.5 2 1.5 2 0 -3 2 2
0];
% Mobile Location Y Coordinate = MY.
MY = [-1 0.5 -1.5 -1.5 2.5 -0.5 1 -1.5 -1 -1 1 0.5 1.5 3.5 0.5 0 1 -2 -
1 -4];
% Location of Base Stations.
% Base Station Location X Coordinate = BX.
BX = [4.5 -2.5 -2.5];
% Base Station Location Y Coordinate = BY.
BY = [0 4 -4];
% Initialize several vectors for values for each node
% Distance from Base Station
% Location SNR
% Distances from Base Station.
distancefromBS1  = zeros(1,N);
distancefromBS2  = zeros(1,N);
distancefromBS3  = zeros(1,N);
% Calculating distances between each mobile and each base station.
for j=1:N
    distance1 =  sqrt(abs(((BX(1)-MX(j)).^2)+((BY(1)-MY(j)).^2)));
    distancefromBS1(j)= distance1;
    distance2 =  sqrt(abs(((BX(2)-MX(j)).^2)+((BY(2)-MY(j)).^2)));
    distancefromBS2(j)= distance2;
    distance3 =  sqrt(abs(((BX(3)-MX(j)).^2)+((BY(3)-MY(j)).^2)));
    distancefromBS3(j)= distance3;
end
```

- Okamura-Hata model has been used in this project to calculate large scale fading. Large scale fading was observed over long distances. Based on the distances from the three eNodeBs, location SNR is calculated for each user with respect to three eNodeBs using the Okamura-Hata model. The following is the code used for large scale fading:

```
for j=1:N
    Fc1=950;  % Carrier frequency for Base Station 1
    Fc2=920;  % Carrier frequency for Base Station 2
    Fc3=930;  % Carrier frequency for Base Station 3
    Hb1=60;   % Base station 1 antenna height
    Hb2=60 ;   % Base station 2 antenna height
    Hb3=60;   % Base station 3 antenna height
    Hm=5;     % Mobile station antenna height
    EIRP=30;
    Gm=0;     % Antenna groups in of the mobile (in dB)
    a1= ((1.1*log10(Fc1)-0.7)*Hm)-(1.56*log10(Fc1)-0.8);
    a2= ((1.1*log10(Fc2)-0.7)*Hm)-(1.56*log10(Fc2)-0.8);
    a3= ((1.1*log10(Fc3)-0.7)*Hm)-(1.56*log10(Fc3)-0.8);
    A1 = 69.55+26.16*log10(Fc1)-13.82*log10(Hb1)-a1;
    A2 = 69.55+26.16*log10(Fc2)-13.82*log10(Hb2)-a2;
    A3 = 69.55+26.16*log10(Fc3)-13.82*log10(Hb3)-a3;
    B1 = 44.9-6.55*log10(Hb1);
    B2 = 44.9-6.55*log10(Hb2);
    B3 = 44.9-6.55*log10(Hb3); C = 0;
    L1 = A1+B1*log10(distancefromBS1(j))+C;
    L2 = A2+B2*log10(distancefromBS2(j))+C;
    L3 = A3+B3*log10(distancefromBS3(j))+C;
    Pr1 = EIRP-L1+Gm;  % Received power
    Pr2 = EIRP-L2+Gm;
    Pr3 = EIRP-L3+Gm;
    Pn = -174+10*log10(180e3);  % Thermal noise for 180kHz channel
    SNR1 = Pr1-Pn;
    SNR2 = Pr2-Pn;
    SNR3 = Pr3-Pn;
    locationSNRbyBS1(j)=SNR1;
    locationSNRbyBS2(j)=SNR2;
    locationSNRbyBS3(j)=SNR3;
    stdshadow=2; % Standard deviation for log-normal shadowing
end
```

In large scale fading the distance is inversely proportional to the SNR. Hence, the longer the distance from enodeB the less SNR the user experiences

- The Rayleigh fading model has been used in this project to calculate small scale fading. Rayleigh fading was simulated using Clarke's model [7].
- After calculating each user's Location SNR using large scale fading, Rayleigh fading or small scale fading was added to calculate actual SNR of a user with respect to three eNodeBs.

```
% This gives actual SNR variation around the mean of locationSNR
actualSNRbyBS1(j) = locationSNRbyBS1(j) + 10.*log10(rmatrix(j,j,1).^2);
actualSNRbyBS2(j) = locationSNRbyBS2(j) + 10.*log10(rmatrix(j,j,1).^2);
actualSNRbyBS3(j) = locationSNRbyBS3(j) + 10.*log10(rmatrix(j,j,1).^2);
```

- This table is used to map SNR to CQI classes and to DL throughput per Resource Block (RB). Different modulation schemes can be used for different throughput.

```
SNRclasses=  [24.4  22.7 18.2 16.4  11.2  9.4  6.4];
CQI = [7 6 5 4 3 2 1];%CQI for corresponding SNR
DLthroughput=[0.8142 0.5980 0.4331 0.2657 0.1578 0.0678 0.0274];
%Throughput per Resource Block (180KHz)
```

The above Downlink Throughput was calculated using [8] taking the sub carrier bandwidth of 180 KHz.

- The services being used by the subscribers are bearers named after their weights

```
services = [1 3 4 8 9 10];
```

- The minimum throughput requirements and the maximum throughput requirements for the above services are as follows

```
minthroughput=[0.03 1.2 0.4 0.512 0.128 0.128];
maxthroughput=[0.1 1.5 0.5 2 0.03 0.03];
for l= 1:length(services);
    serviceminthroughput(l)=minthroughput(l);
    servicemaxthroughput(l)=maxthroughput(l);
end
```

- The services used by the bearers are changed for every 5000 slots. This data is randomly predesigned and imported from an Excel sheet.

```
%%%%%%%%%%%%%%%%%%%%%%%%% For enodeB1%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
 % Giving Weights and Priority
           if (i1<=bk)
               WforBS1 = data1(M,:);
           else
               bk = bk+servicechange;
               M = M+1;
               WforBS1 = data1(M,:);
           end
```

- Once the services were imported and implemented, we mapped the minimum throughput and maximum throughput to the users depending upon the RBs availability or spectrum availability. Also, we counted the number of RB's allocated to each user. The following table furnishes the mapping of the throughput:

```
%%%%%%%%%%%%%%%%  For Base Station 1  %%%%%%%%%%%%%%%%
            % SNR to CQI
            if (actualSNRbyBS1(j)>SNRclasses(1))
                CQIforBS1(j) = CQI(1);
```

```
                for l = 1:6;
                    if (WforBS1(j)==services(l))
                        if (RBforBS1(j)<20)
                        actualthroughputbyBS1(j)=
servicemaxthroughput(l);
                        else
                        actualthroughputbyBS1(j)=
serviceminthroughput(l);
                        end
                        RB1s=
ceil(actualthroughputbyBS1(j)/DLthroughput(1));
                        RBforBS1(j)=RB1s;
                    end
                end

            else
                for k=1:length(SNRclasses)-1
                    if (actualSNRbyBS1(j)<=SNRclasses(k)) &&
(actualSNRbyBS1(j)>SNRclasses(k+1))
                        CQIforBS1(j) = CQI(k+1);
                        for l = 1:6;
                            if (WforBS1(j)==services(l))
                                 if (RBforBS1(j)<20)
                                    actualthroughputbyBS1(j)=
servicemaxthroughput(l);
                                 else
                                    actualthroughputbyBS1(j)=
serviceminthroughput(l);
                                 end
                                RB1s=
ceil(actualthroughputbyBS1(j)/DLthroughput(1));
                                RBforBS1(j)=RB1s;
                            end
                        end
                    end
                end
            end
            if (actualSNRbyBS1(j)<SNRclasses(length(SNRclasses)))
                CQIforBS1(j) = 0;
            end
            TRBforBS1 = sum(RBforBS1); %Caluculation of total number
of RBs per BS1
        end
        %%%%%%%%%%%%%%%%  For Base Station 2  %%%%%%%%%%%%%%%%
        % SNR to CQI
            if (actualSNRbyBS2(j)>SNRclasses(1))
                CQIforBS2(j) = CQI(1);
```

```
                for l = 1:6;
                    if (WforBS2(j)==services(l))
                         if (RBforBS2(j)<20)
                            actualthroughputbyBS2(j)=
servicemaxthroughput(l);
                         else
                            actualthroughputbyBS2(j)=
serviceminthroughput(l);
                        end
                        RB2s=
ceil(actualthroughputbyBS2(j)/DLthroughput(1));
                        RBforBS2(j)=RB2s;
                    end
                end

            else
                for k=1:length(SNRclasses)-1
                    if (actualSNRbyBS2(j)<=SNRclasses(k)) &&
(actualSNRbyBS2(j)>SNRclasses(k+1))
                        CQIforBS2(j) = CQI(k+1);
                        for l = 1:6;
                            if (WforBS2(j)==services(l))
                                 if (RBforBS2(j)<20)
                                     actualthroughputbyBS2(j)=
servicemaxthroughput(l);
                                 else
                                    actualthroughputbyBS2(j)=
serviceminthroughput(l);
                                end
                                RB2s=
ceil(actualthroughputbyBS2(j)/DLthroughput(1));
                                RBforBS2(j)=RB2s;
                            end
                        end
                    end
                end
            end
            if (actualSNRbyBS2(j)<SNRclasses(length(SNRclasses)))
                CQIforBS2(j) = 0;
            end
            TRBforBS2 = sum(RBforBS2); %Caluculation of total number
of RBs per BS1

            %%%%%%%%%%%%%%%%  For Base Station 3  %%%%%%%%%%%%%%%%

    % SNR to CQI
                if (actualSNRbyBS2(j)>SNRclasses(1))
```

```
                    CQIforBS2(j) = CQI(1);
                    for l = 1:6;
                        if (WforBS2(j)==services(l))
                            if (RBforBS2(j)<20)
                                actualthroughputbyBS2(j)=
servicemaxthroughput(l);
                            else
                                actualthroughputbyBS2(j)=
serviceminthroughput(l);
                            end
                            RB3s=
ceil(actualthroughputbyBS2(j)/DLthroughput(1));
                            RBforBS2(j)=RB3s;
                        end
                    end

                else
                    for k=1:length(SNRclasses)-1
                        if (actualSNRbyBS3(j)<=SNRclasses(k)) &&
(actualSNRbyBS3(j)>SNRclasses(k+1))
                            CQIforBS2(j) = CQI(k+1);
                            for l = 1:6;
                                if (WforBS3(j)==services(l))
                                    if (RBforBS3(j)<20)
                                        actualthroughputbyBS3(j)=
servicemaxthroughput(l);
                                    else
                                        actualthroughputbyBS3(j)=
serviceminthroughput(l);
                                    end
                                    RB3s=
ceil(actualthroughputbyBS3(j)/DLthroughput(1));
                                    RBforBS3(j)=RB3s;
                                end
                            end
                        end
                    end
                end
                if (actualSNRbyBS3(j)<SNRclasses(length(SNRclasses)))
                    CQIforBS3(j) = 0;
                end
                TRBforBS3 = sum(RBforBS3); %Calculation of total
number of RBs per BS1
            end
```

- The next step was to decide which one of the groups was to be given the instantaneous time slot. A new scheme was used for this. Tmfmetric for all the users is calculated for each time slot. The top numbers of each group were aggregated with best TMF metric in each group and this group was chosen for that instantaneous slot.

```
 for Gindex=1:groups
  % Find the elements in tmfmetric for this group, which go
  % from startindex(Gindex) to starindex(Gindex+1)-1, then
  % sort them.
sortvect=tmfmetricforBS1(startindex(Gindex):startindex(Gindex+1)-1);
sortvect=[sortvect
tmfmetricforBS2(startindex(Gindex):startindex(Gindex+1)-1)];
                    sortvect=[sortvect
tmfmetricforBS3(startindex(Gindex):startindex(Gindex+1)-1)];
                    sortvect=sort(sortvect,'descend');
% Find the sum of the largest "topnum" values in the group
 topnum=3;
    for iii=1:topnum
    G(Gindex)=G(Gindex)+sortvect(iii);
    end
end
```

- Once a group was selected, the user in that group was chosen by one enodeB which has good radio conditions and is not selected by the other two eNodeBs at same time slot.

```
BSchosen=[];

for BSchoice=1:3


[Y1,II1]=max(metricforBS1(:,startindex(Gmaxindex):startindex(Gmaxindex+
1)-1));% Mobile I is the best
```

```
 % Y1 is the best value, II1 is the index

[Y2,II2]=max(metricforBS2(:,startindex(Gmaxindex):startindex(Gmaxindex+
1)-1));
% Mobile I is the best
[Y3,II3]=max(metricforBS3(:,startindex(Gmaxindex):startindex(Gmaxindex+
1)-1));% Mobile I is the best
                        choicevector=[Y1 Y2 Y3];
                        for choiceindex=1:length(BSchosen)
                            choicevector(BSchosen(choiceindex))=0;
                        end
                        [Ymax,IImax]=max(choicevector); % IImax gives
the BS number
                        if IImax==1
                            II=II1;
                        else if IImax==2
                                II=II2;
                            else
                                II=II3;
                            end
                        end
```

- The concluding step in the code was to calculate the total group throughput. We did this by summing up all the user throughputs in that group. In addition to this, RBs and time slots that have been given to a particular user and to the group were calculated.

CHAPTER 5

RESULTS AND ANALYSIS

This section provides analysis of the performance of the metrics that were formulated in this project. The initial step here is to understand the basic behavior of the approach.

First the scheduler aimed to serve at least minimum throughput to satisfy a GBR bearer irrespective of GBR service used. Then the leftover RBs were allocated to the NGBR users. If still if the scheduler had abundant resources it aimed to provide maximum throughput to the GBR service used.

In this case, a new scheduling scheme was used between the groups to choose the best group. Then to choose a user inside the group, a scheduling scheme was implemented which was a function of type of service used, channel conditions and fairness.

The following simulation results:

Table 3: Simulation Parameters

Parameter	Configurations	
Cell Layout	3 eNodeBs with 5MHz band (~20RBs), 20 UEs randomly distributed between three overlapping coverage cells and belongs to 5 groups and are self-organized.	
Channel Model	Large scale fading and Rayleigh Fading.	
Sub Carrier Spacing	180 KHz	
Scheduler Model	Time slots for each enodeB	20000
	Types of Service and Weights	See Table 2

Consider users with different channel conditions and multi-QoS requirements. The following illustrates the plots of users SNR with respect to all the three eNodeBs.

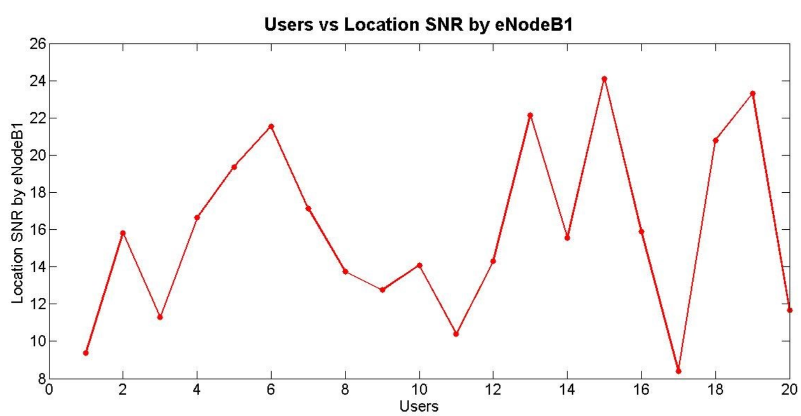

Fig. 2: Users vs Location SNR by eNodeB1

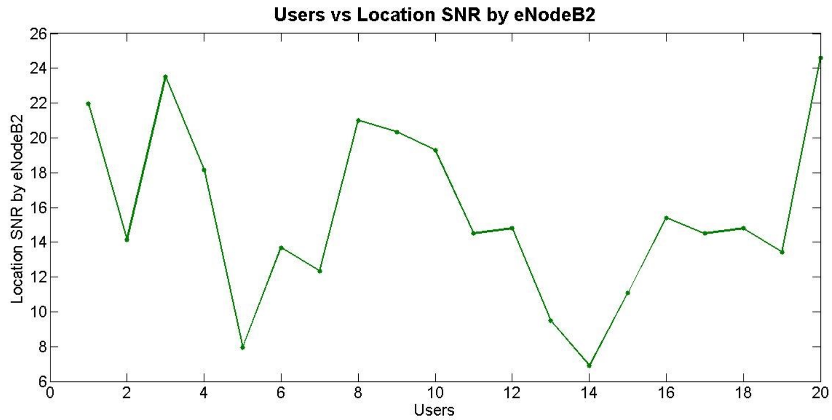

Fig. 3: Users vs Location SNR by eNodeB2

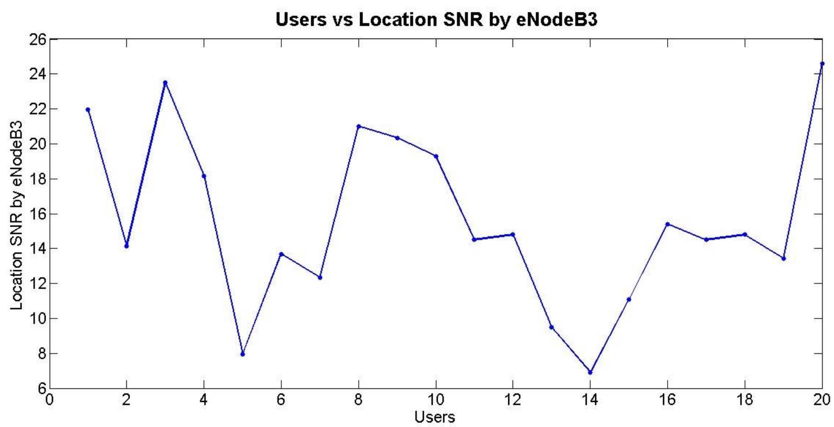

Fig. 4: Users vs Location SNR by eNodeB3

The users experienced overlapping coverage by three eNodeBs and each of them had their respected SNR with each of the base stations.

Users in the group used the services and were assumed to change the services for every 5000 time slots. The following plot conveys the users and services: used for every 5000slots.

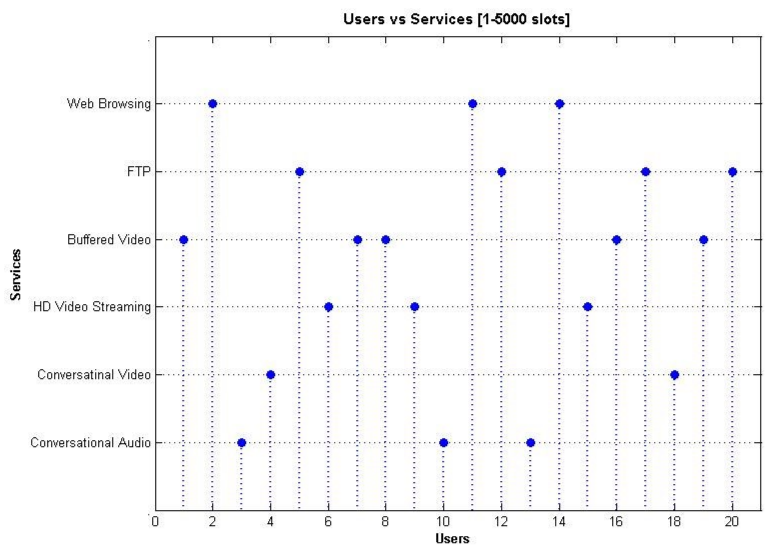

Fig. 5: Users vs Services [1-5000 Slots]

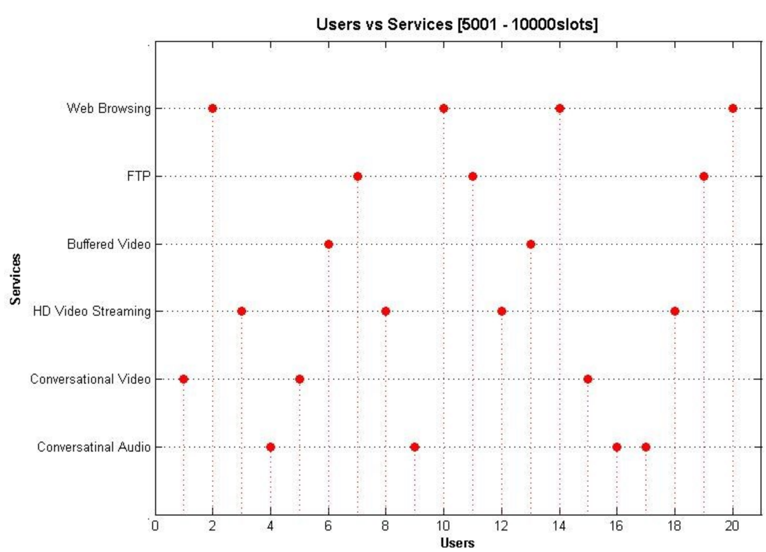

Fig. 6: Users vs Services [5001-10000 Slots]

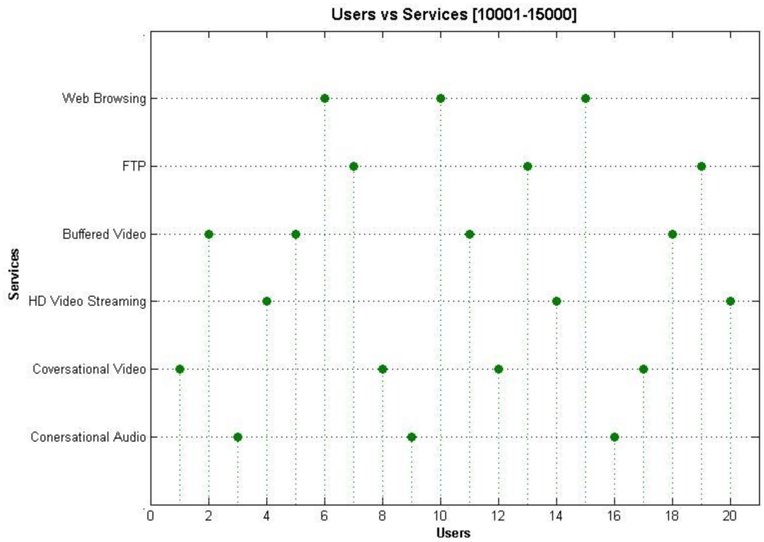

Fig. 7: Users vs Services [10001-15000 Slots]

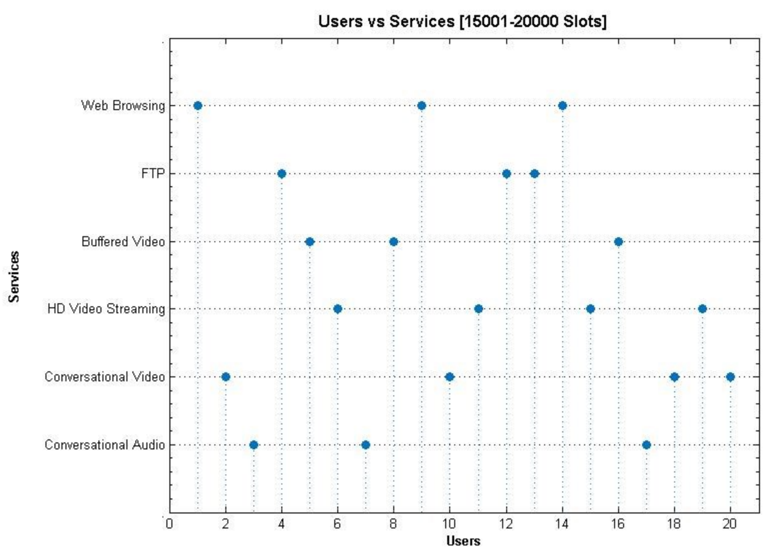

Fig. 8: Users vs Services [15001-20000 Slots]

The simulation results for throughput are carried out in two different cases.

1. Case 1 – With no limitation for Resource Blocks allocated
2. Case 2 – When each eNodeB has 20 Resource RBs and sharing according to self–organizing networks fashion.

Case 1

The following plot shows the group throughput results for TMF metric for Case 1 where there are no limitations for Resource Blocks.

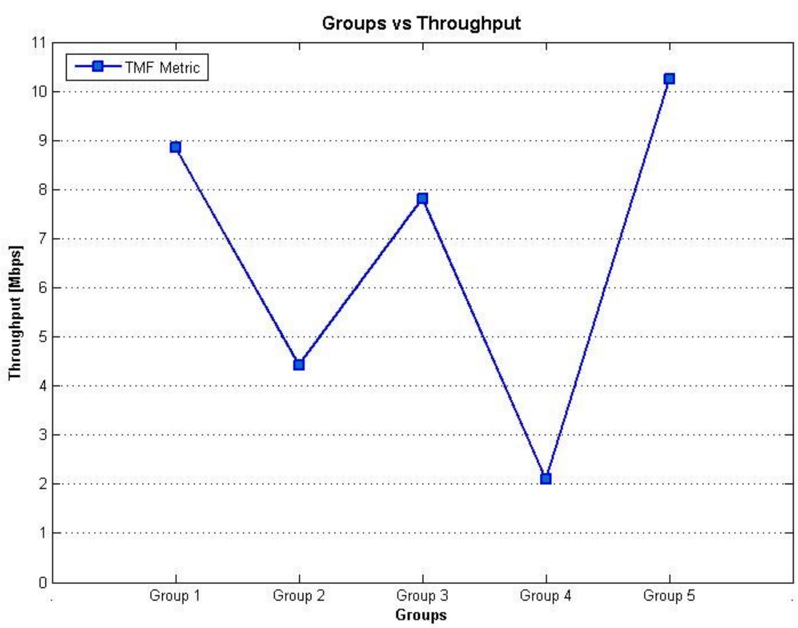

Fig. 9: Groups vs Throughput [Case 1]

The plot shows the throughput achieved by each group when there is no limitation of Resource Blocks at the base station. The TMF metric aims to provide maximum throughput and also tries to maintain fairness among the groups. The total throughput calculated in Case 1 using TMF metric is *33.3 Mbps.*

Similarly, the simulations for group throughput are also carried for Case 1 for Max C/I and PF Metric. The following depicts the comparison graph between TMF, PF and Max C/I Metrics.

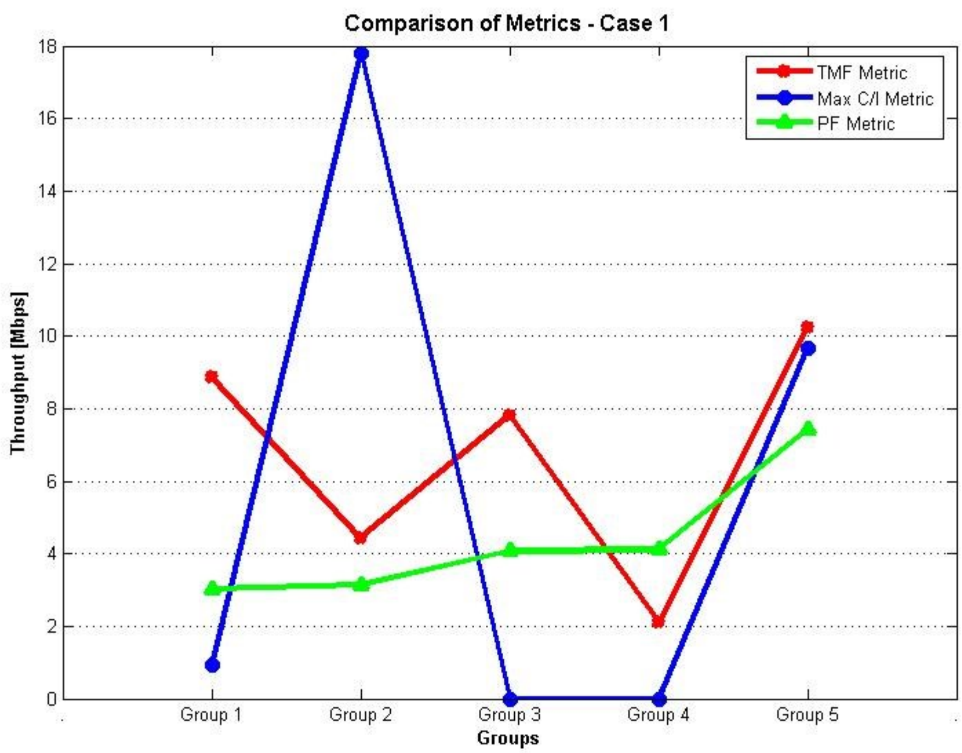

Fig. 10: Comparisons of Metrics [Case 1]

Figure 10 clearly shows how the TMF metric is more viable than the PF and Max C/I Metric. In this case, the Max C/I metric is independent of service and fairness. It only aimed to provide throughput to the user with the best channel conditions and hence it could only provide throughput for 3 groups which left the other two with zero throughput. This also shows that Max C/I is ignoring the fact of providing guaranteed throughput for GBR Users.

On the other hand, PF metric tries to maintain fairness by sacrificing the throughput which results is less efficiency for the system. The PF metric was successful in maintaining fairness among the groups, but failed to provide guaranteed throughput for GBR users because it only considered the fact that the user group with better PF metric will be served. It may either be a GBR user or NGBR user.

The TMF metric is responsible for providing guaranteed throughput for GBR users at any cost. Also, TMF tries to maintain fairness among the groups. The TMF metric is more preferable than the other two because the total throughput achieved is greater than the Max C/I and the PF Metric. The following are total throughput results.

The TMF Metric achieves 33.3 Mbps. The Max C/I Metric achieves 28.9 Mbps and the PF metric achieves 22.7 Mbps which clearly indicates that the TMF Metric is the preferable one.

Case 2

In Case 2 the scheduler puts a limitation on the Resource Blocks per base station. As discussed in Table 3, each base station has 20 Resource Blocks for their users and also three base stations share their resource blocks if required.

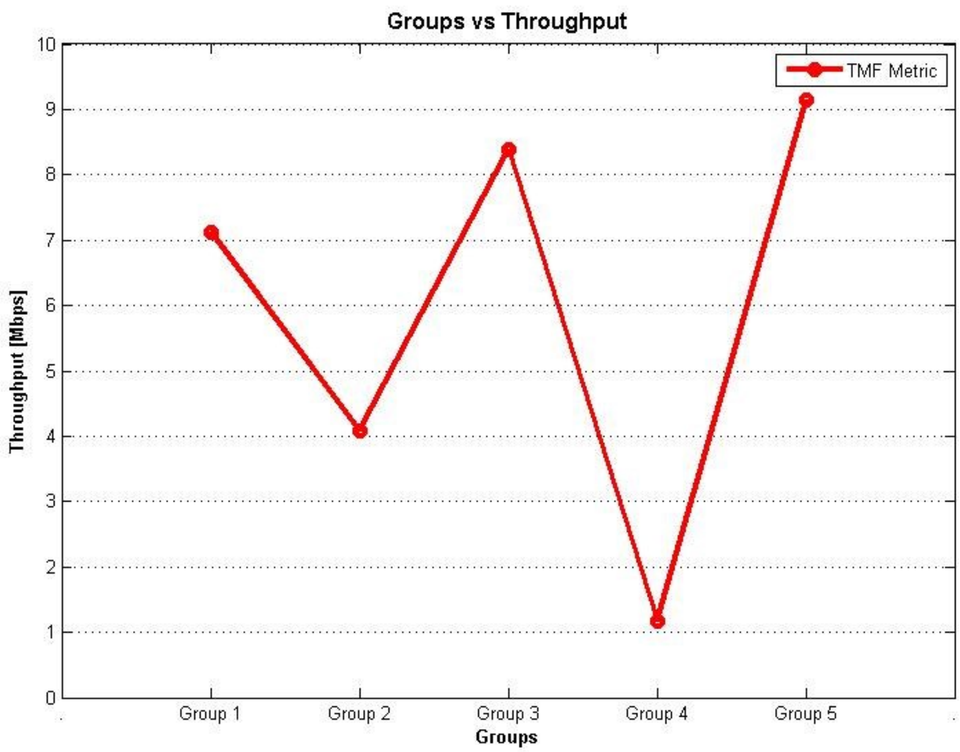

Fig. 11: Groups vs Throughput [Case 2]

The plot shows the throughput achieved by each group when there is no limitation of Resource Blocks at the base station. The TMF metric aims to provide maximum throughput and also tries to maintain fairness among the groups. The total throughput calculated in Case 1 using TMF metric is 30.2 Mbps.

Similarly, the simulations for group throughput are also carried for Case 1 for the Max C/I and the PF Metric. The following depicts the comparison graph between TMF, PF and Max C/I Metrics.

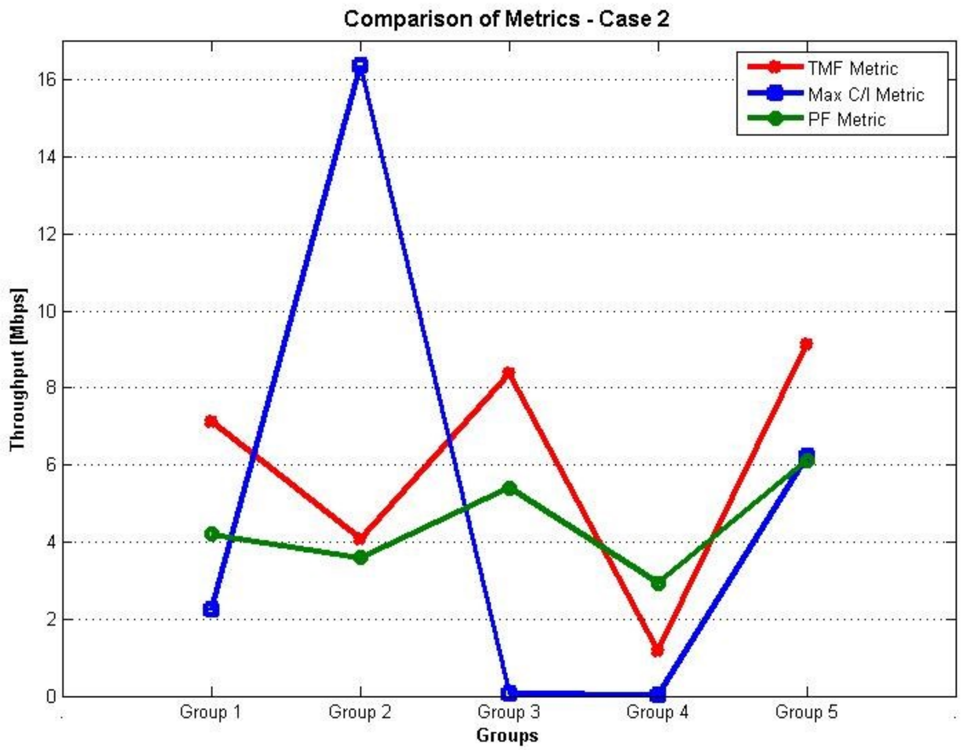

Fig. 12: Comparisons of Metrics [Case 2]

Figure 12 clearly shows that the TMF metric is preferable to the PF and Max C/I Metrics. In this case, the Max C/I metric is independent of service and fairness. It only aims to provide throughput to the user with the best channel conditions and therefore it could only provide throughput for 3 groups and leaves the other two with zero throughput. This also shows that the Max C/I ignores the fact of providing guaranteed throughput for GBR Users.

On the other hand, the PF metric tries to maintain fairness by sacrificing the throughput which results is less efficiency for the system. The PF metric was successful in maintaining fairness among the groups, but failed to provide guaranteed throughput for GBR users because it only consider the fact that the user / group with better PF metric will be served whether it is a GBR user or a NGBR user.

The TMF metric is responsible for providing guaranteed throughput for GBR users at any cost. Also, TMF tries to maintain fairness among the groups. The TMF metric is preferable to the other two because the total throughput achieved is greater than the Max C/I and the PF Metric. The following are total throughput results.

Also, in case 2, base stations share resources to serve their best user / group in order to satisfy GBR and give their minimum required throughput.

The TMF Metric achieves 30.2 Mbps. The Max C/I Metric achieves 24.6 Mbps and the PF metric achieves 21.1 Mbps, which clearly shows that the TMF Metric is preferable.

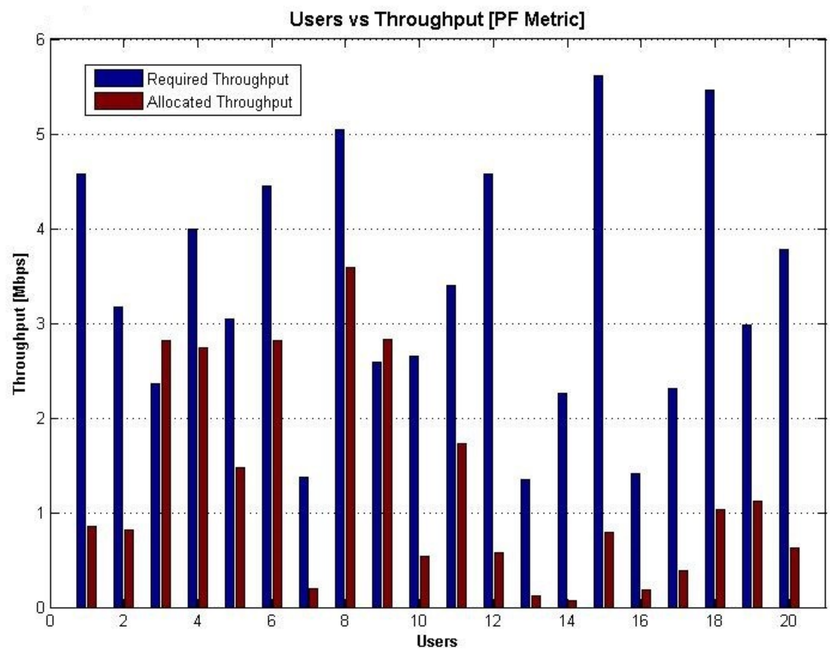

Fig. 13: Users vs Throughput [PF - Case 2]

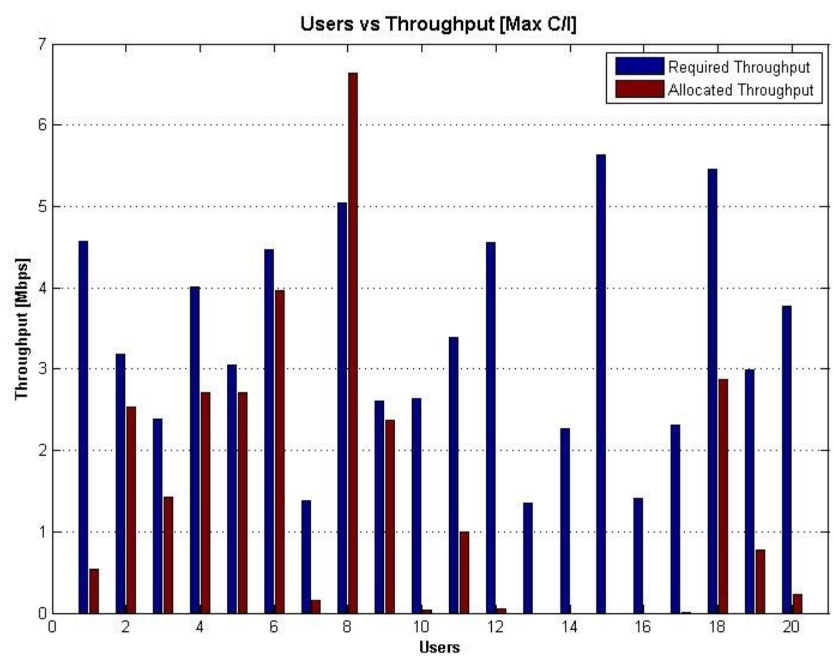

Fig. 14: Users vs Throughput [Max C/I - Case 2]

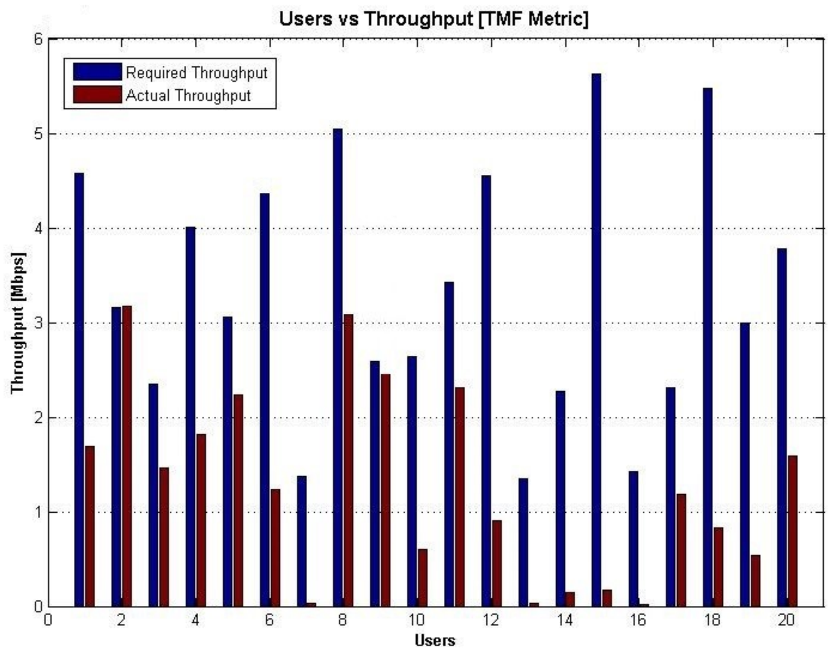

Fig. 15: Users vs Throughput [TMF - Case 2]

Figure 13, 14 and 15 show the plots for users and throughput. The required throughput given in the graph includes the total throughput of the user requiring a throughput for GBR service and NGBR service. The allocated throughput is the GBR service throughput for a user. It is also possible that the NGBR throughput might be given to the user at times.

Furthermore, these three plots show that TMF only provides service for GBR users and also maintains fairness among the users by not neglecting any of them.

The following plot shows the group throughput results for the TMF metric for emergency situations.

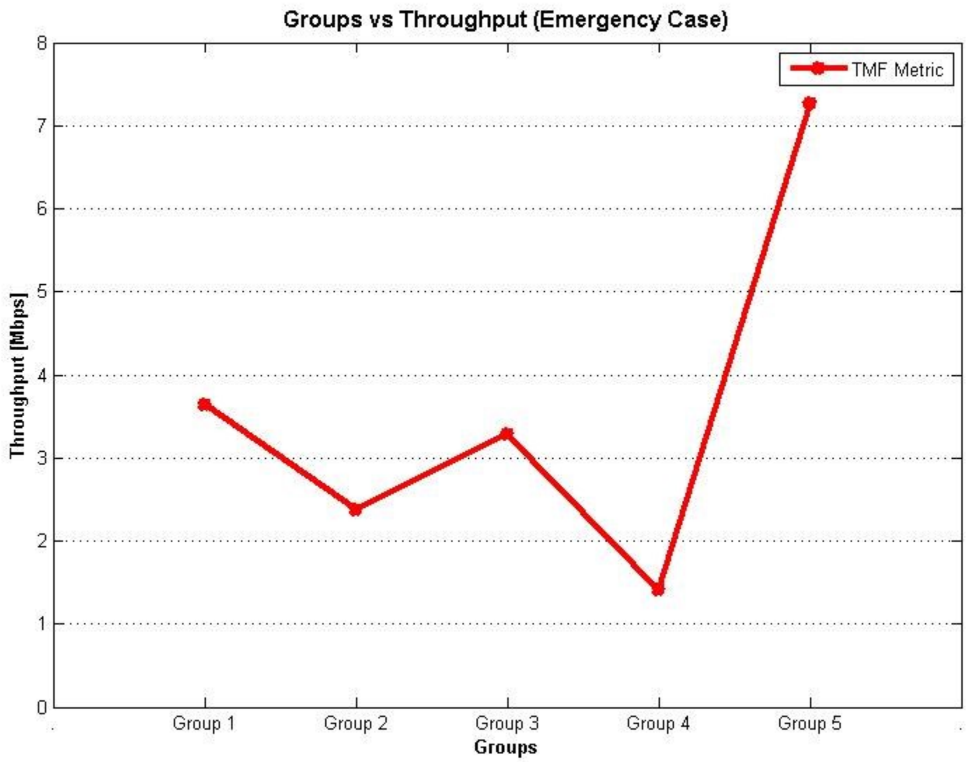

Fig. 16: Groups vs Throughput

The plot shows the throughput achieved by each group. The TMF metric attempts to provide throughput and also tries to maintain fairness among the groups. The total throughput calculated using the TMF metric is 18.1 Mbps.

Similarly, the simulations for group throughput are also used for Case 1 for the Max C/I and the PF Metric. The following depicts the comparison graph between the TMF, PF and Max C/I Metrics.

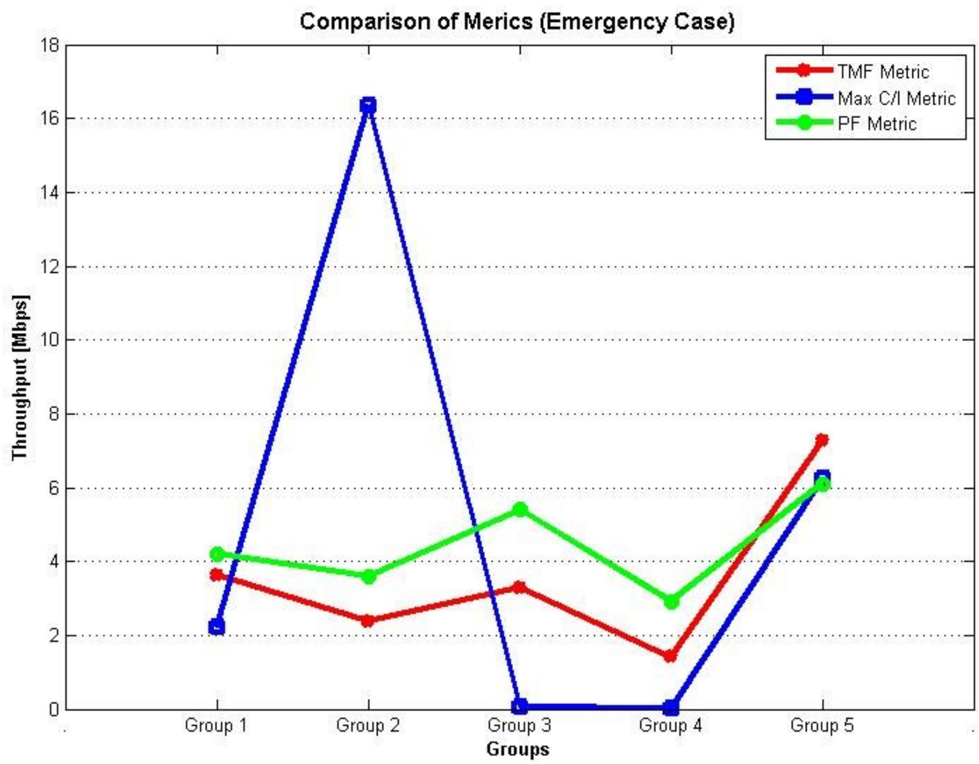

Fig. 17: Comparisons of Metrics

Figure 17 clearly shows that TMF is metric is preferable to the PF and Max C/I Metrics. In this case, the Max C/I metric is independent of service and fairness. It only aims to provide throughput to the user with best channel conditions and therefore it could only provide throughput for 3 groups, leaving the other two with zero throughput. On the other hand, the PF metric attempts to maintain fairness by sacrificing the throughput which results is less efficiency for the system. The PF metric was successful in maintaining fairness among the groups but failed to provide better total throughput.

The TMF tries to maintain fairness among the groups. The TMF metric is preferable to the other two because the total throughput achieved is greater than the Max C/I and PF Metrics. The following are total throughput results.

The TMF Metric achieves 18.1 Mbps. The Max C/I Metric achieves 17.9 Mbps and the PF metric achieves 12.1 Mbps which clearly shows that the TMF Metric is preferable.

CHAPTER 6

CONCLUSION

The project presented the concept and algorithm for self-organized group scheduling in a multi cell scenario. This kind of scheme automatically triggers reconfiguration of the eNodeBs and its parameters with respect to the changing channel conditions and variable service demands. This algorithm is opportunistic as well as fair at both the group and user level. The group scheduling is implemented to satisfy the multi-QoS requirements of the users. The users in this scenario are the combination of the public safety organizations and normal subscribers. Furthermore, a SON-based situation aware scheduling approach has been designed providing fairness among users with the use of PF. The trade-off between the throughput and fairness has been achieved with the use of the TMF metric which also displays the priorities of the services.

This project also evaluates the system performance in the case of emergency and allocation of all the users providing fairness and reasonable throughput to all the bearers. In other words, it describes how well the system behaves when compared to how well it is could perform assuming there is no allocation from one side. This concept has been proven to be successful in attaining the system level efficiency and user level satisfaction with the show results.

The main objective of the thesis is to provide fairness and maximize the throughput for PS organizations by prioritizing them over the normal users. The overall system also has increased throughput. This has been achieved and found to be a feasible algorithm.

6.1 Future Scope

The future work should include the following considerations in addition to the proposed algorithm

- Finding the optimal solution for the TMF metric
- Adding the aspect of Multi user MIMO, beamforming.
- Design a group scheduling scheme that can be suitable for the mobility environment in urban areas.
- Group scheduling in the uplink.
- Group scheduling in the case of heterogeneous networks and relay nodes.
- Scheduling and prioritizing the users for new services like VoLTE, VoLGA, and Real Time Communications etc.

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VITA

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In 2012, he was admitted into the Master of Science in Electrical Engineering department at University of Missouri Kansas City, Kansas City, MO. He was awarded the Dean's International Scholarship Award for this program. He is expecting to graduate in December 2014.

Upon the completion of the degree, he plans to work as a Telecom Engineer in the future.