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# Multihop D2D Communication to minimize & balance SAR in 5G

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*Abstract:* As the technology grows, we move towards the higher frequency bands in order to achieve better performance , there is exponential rise in the advancement & growth of the mobile technology due to which there is increase in traffic. In this regards we encounter a lot of issues & challenges to be taken care of as we move towards higher frequency bands, one such concern is the SAR, This has harmful effect due to the associated EMF , which is termed as specific absorption ratio (SAR). We have to consider the impact of electro magnetic field & its exposure in the 5G technology & also understand the significance of SAR as an ideal measurement for safer exposure level . To understand this concern we should analyze the possible requirements of 5G & it's risks , reduction in the exposure to EMF , Analysis of SAR ,different proposed techniques to reduce it in the mobile communication network.

**Index Terms - D2D,5G,SAR**

## I. INTRODUCTION

With increase in popularity of smart devices , the network requirements have also increased in the last decade , we have seen the evolution of mobile wireless communication & how currently the LTE in use has become a part of our daily life . the most popular frequency range in wireless technology is 300MHz to 3GHz, but the current challenge is to accommodate the traffic & connectivity which is expected out of the sub millimeter wave (mmWv) . It is expected that there are going to be 1.9 billion devices working on 5G by the end of 2024, out of which 60% would be the smart phones, the concern here would be the RF exposure in time & space domains due to beamforming & MIMO technology used in 5G,.It is observed that for every four years the volume of the wireless traffic is getting doubled .The major requirements from 5G is the date rate up to 10Gbps which is practically 10 times of that in the current 4G , 1ms latency , higher bandwidth & higher the number of connected devices , 5G also aims at 99% availability , anytime anywhere coverage , to practically achieve all these requirements we are moving towards the frequency spectrum above 6GHz which is likely to operate in 5G has significant risks .

It is a fact that EMF has negative effects on human body , increase in data rate simply corresponds to higher signal power at the receiver , considering this on a large scale deployment the risks increase exponentially. Since 5G is expected to work on the millimeter wave technology , the millimeter waves are a concern because on long exposure it can be absorbed by the dermis &epidermis of the skin, which also increases & causes heating effects on the body, It causes basic health risks like stress, tiredness , poor concentration & is also capable of changing the chemical structure of the tissue , changes the electrical balance in the body resulting in organ damage , possibility of skin cancer & increase in human body temperature Practically, if we compromise on the frequency , then the network coverage decreases, we would need more number of antennas & base stations , which in turn creates a lot of cost implications. The main aim is to reduce SAR by using the techniques of multihop D2D technology.

### D2D COMMUNICATION

the concept of resource allocation of power , frequency, time & node selection which can be optimally utilized even in case of absence of base station or access points. Commercially the operators are proposing new business models keeping a D2D communication as the primary focus because it gives the edge of saving the spectrum & also provides proximity services. In D2D communication the user equipment are capable of using low frequency resources & hence interchange information directly unlike the traditional approach where the information has to travel via base station.

D2D communication due to the benefit of offloading data at the base station in the cellular network & supporting peer to peer co-operative, multi-hop communication in the cellular network has paved way for research as we move towards higher frequency in 5G & future 6G networks. In terms of application this has a major role in sharing resources that are close to each other (user equipment) therefore this can be applied primarily in mobile cloud computing, as a result this is a transparent communication system.

A. D2D underlay-overlay communication:

Attenuating the problem of interference can be controlled as relay communication nodes. Link establishment which is a challenging approach in a co-operative & non co-operative environment where resource allocation, connection control, access authentication is a challenging situation. D2D user will primarily reuse the downlink frequency which in turn helps to mitigate interference & also in mode selection. The primary focus can a be to reduce the power consumption.

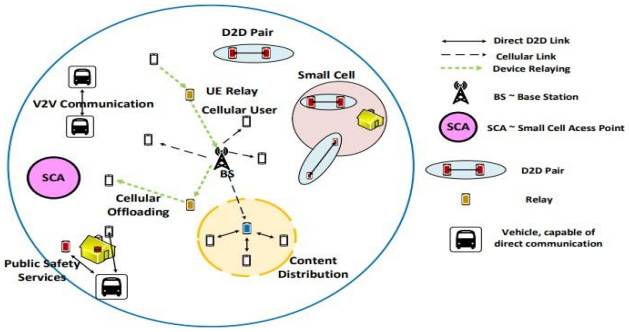



Fig.1. A General Scenario supporting device-to-device (D2D) communication

We know that the 4G network was base station centric, where as in 5G we are moving towards device centric approach & hence D2D communication can be seen as a probable future, because it gives better spectral efficiency, reduces latency & also gives the desired throughput. D2D in 5G network can be considered in 2 tyres such as the macro cell tyre & the device tyre. In this approach the base station will either have full or partial control. Hence we can categorize into 3 types

1. Control link can be established by device relaying in areas of poor coverage or at cell edges, where information relaying can happen via base station.
2. Control link establishment can be seen between devices directly where the links are provided via base station.
3. We can follow an architecture by the concept of controlled link device relaying where resource allocation , cell setup , management of interference can be taken care by the user equipment themselves.

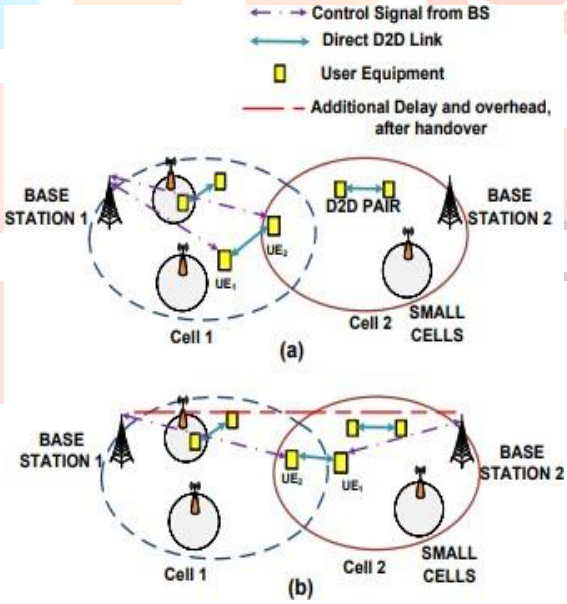



Fig.2 Regular Handover Scenario, (a) Before Handover; (b) After Handover from cell1 to cell2

The benefits of D2D communication are as follows:

1. Since the users communicate with each other based on the nearest neighbor approach this can be seen as a one hop-communication & hence gives us an efficient spectrum utilization & the desirable latency.
2. The spectrum which is used by the cellular users is shared by the D2D users as well. Therefore this improves the spectrum reuse ratio.
3. D2D communication enhances the battery life by power level optimization which clearly means higher energy efficiency is achieved.
4. The coverage area is improved

In contrast D2D communication also attracts a lot of research since we face challenges such as feasibility of communication with restriction in the distance & also the interference across the different tyres.

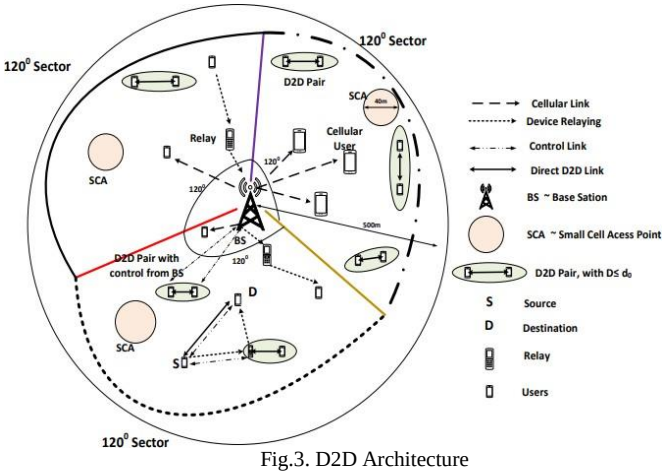



Fig.3. D2D Architecture

B.Millimetere wave D2D communication:

We know that the 5G technology is effectively going to work on millimeter waves in the band 30GHz to 300Ghz. Hence at this high frequency by making use of D2D communication in the future generations. With the help of relays if the line of sight path is blocked & then a new path is developed between the associated devices which are connected over a base station via hopping, therefore the concept of multi-hop D2D communication, can create a co-existence of base station to base-station, device to base station. This can observed in two types as underlay & overlay, underlay D2D direct links are setup using the spectrum, in overlay a dedicated spectrum is assigned for D2D communication. The radio interfaces in case of D2D is managed by eNB. Instead the devices communicating between each other, we can use eNB as the relay just like the conventional cellular mode. Since D2D communication is characterized with a lot of network parameters & channel conditions.

In the future prospect we can analyze different models & also apply the machine learning concepts to model the complex algorithms, resource allocation & optimization, & programming explicitly. Machine learning also enables the D2D network to compute the required communication steps intelligently & hence the concepts of artificial intelligence can be applied for the D2D network.

SAR

Since we are moving towards the higher frequency bands in the 5G networks, there is a concern of EMF exposure, focused on frequency above 6GHz which is capable of shallow penetration. SAR should be considered as the primary constraint in the 5G system both in uplink & downlink, due to significant increase in SAR in the recent times which has potential impact on human health. In order to full fill the data rates the signal power is also tremendously increasing as compare d to 3GPP & the current 4G technology. So, the harmful effects are measured in terms of the parameter Specific Absorption Rate (SAR), The effect of EMF depends primarily on the transmission power & frequency.

The exposure to higher level of EMF's can create electrical imbalance in the body leading to potential impairment of organs, cognitive functions, disrupting the chemical structure of the tissues, also skin cancer in higher levels. Therefore in research perspective the analysis & minimization of SAR becomes the primary focus. We have to come up with the protocols which keeps the SAR level intact, & EMF exposure at safer levels.

In research perspective the indoor EMF exposure using 5G wi-fi as suggested in 802.11 specification can impose higher threats. Hence to mitigate this we have to setup a threshold that follows the protocols serving AP & user equipment, also considering the power reduction & antenna array technology. SAR value can be analyzed theoretically & practically considering different scenarios & eco-systems. By considering the distance of separation between the body & user equipment. By considering the traffic path & the frequency of operation. From information theory point of view. Shannon Hartley theorem can be considered to estimate signal to nice power ratio at the reciever The power analysis can be done keeping the noise level as a consideration for the analysis of SAR. In this analysis free space path losss model is considered to determine the field strength & the Effective distance from which we can get the SAR,Received signal analysis has to be done keeping downlink direction to UE. The concept of antenna being forming gained is also considered for the SAR analysis Therefore.we can conclude the analysis of SAR has to be done with different proposed protocols considering the different constraints of uplink downlink in 5G system & effectively come up with a standard SAR permissible value for the future 5G network which operates at higher frequency.

## II. QUANTITATIVE MEASURE OF SAR

From the definition of SAR,

$$SAR = \frac{\sigma E^2}{\rho} \quad (1)$$

SAR (W att/kg), E (V /m) is the electric field, σ(S/m) is the tissue conductivity and mass density of the tissue is ρ(kg/m3 )

By considering Shannon-hartley theorem, for the SAR where , SNR is the signal to noise power ratio at the receiver, , k is transmission rate in bits/second, B is the channel bandwidth in Hz

$$SNR_r = 2^{k/B} - 1, \quad (2)$$

By considering constant noise & minimum power at the receiver, we arrive at equation (3)

$$P_{r_{min}} = N_0(2^{k/B} - 1) \quad (3)$$

By considering Free Space Path Loss model, to receive a minimum power Prmin at the receiver at distance D from the transmitter, the minimum transmission power should be

$$P_{t_{min}} = G(\frac{4\pi Df}{c})^2(N_0(2^{k/B} - 1)) \quad (4)$$

where, G is a system dependent constant, D is the distance between transmitter and receiver, f is the frequency of transmission and c is the speed of light in free space. Now for a transmitter, transmitting with a power Ptmin , the power density at a distance dr

$$P_{d_{min}} = \frac{P_{t_{min}}}{4\pi d_r^2} watts/m^2 \quad (5)$$

From Poynting's theorem, the cross product of electric field vector E and the magnetic field vector H at any point is a measure of the rate of flow of electromagnetic energy per unit area at that point, given by

$$P_d = E \times H \ watts/m^2 \quad (6)$$

from the theory of electromagnetic radiation propagation, assuming the impedance of free space to be approximately 120πΩ,

$$E|_{dr} = \frac{\sqrt{30P_{t_{min}}}}{d_r} \quad (7)$$

So, we get minimum SAR value at that point, from equation (1) ,

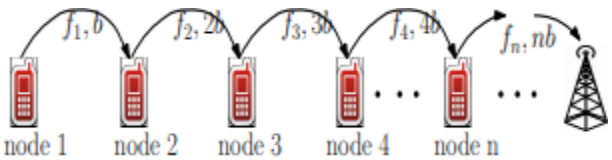
$$SAR_{min} = \frac{\sigma(4\pi GDf)^2 30N_0(2^{k/B} - 1)}{\rho(d_r c)^2} \quad (8)$$

Equation (8) shows for wireless transmission, t minimum SAR value at point X depends on parameters like,), distance of X from the transmitter (dr), the frequency of operation (f), distance between transmitter and receiver (D, bit rate (k), bandwidth (B) of communication.

## III. SAR BALANCED ROUTING & ANALYSIS

In a wireless network which has a shorter communication range it is obvious that the frequency band in which it is operating is less harmful when we consider SAR by using multi hot network in 5Gtechnology ,Also by using the concept of multi hopping multipath hopping it gives us a good option in terms of energy- efficient routing this can be achieved by using the concept of nearest neighbour routing that is the NNR.The concept of nearest neighbour routing can be achieved by forwarding the data packet in a multi hope path that is for which to achieve we need a power required at individual notes to be satisfied and also an estimation of total power at the end of the path this is the concept ofnearest neighbour row thing whereas the forward of the data packet load imbalance in a multi hop network ,also considering the packet routing ,hence balancing of SAR in can be applied to any random network for the evaluation Hence by using the concept of nearest neighbours routing we can conclude that the notes will be able to effectively transfer the data with less power consumption.

Each node which acts as the user equipment that is considered in the network the forwarding of the data packets happens from one node to the other and finally to the base station so by considering this the concept of relating the nearest neighbour Routing will effectively decrease the SAR value across all the notes but higher data transfer rate will also result in higher SAR value,There fore in order to balance the SAR value we assign different frequency bands at different notes depending upon the load they can carry so finally the objective of this is to achieve better frequency allocation.




Our aim is to achieve, SAR1 = SAR2 = SAR3 = . . . = SARn

So, from equation (8), assuming all other parameters to be same for the network, we have

$$(2^{k/B}-1)f_1^2=(2^{2k/B}-1)f_2^2=\ldots=(2^{nk/B}-1)f_n^2$$

$$or,(2^{k/B}-1)f_1^2=(2^{nk/B}-1)f_n^2$$

For a given frequency spectrum of operation, (fmax − fmin) the maximum frequency band fmax can be assigned to the node with minimum load, i.e. node-1, and an upper bound on the value of n can be attained as

$$n\leq\frac{B}{k}\log_2\left(\left(\frac{f_{max}}{f_{min}}\right)^2(2^{\frac{k}{B}}-1)+1\right) \qquad (9)$$

Here, n is the number of nodes in a linear network where SAR values are balanced for all nodes.

## IV. RESULTS

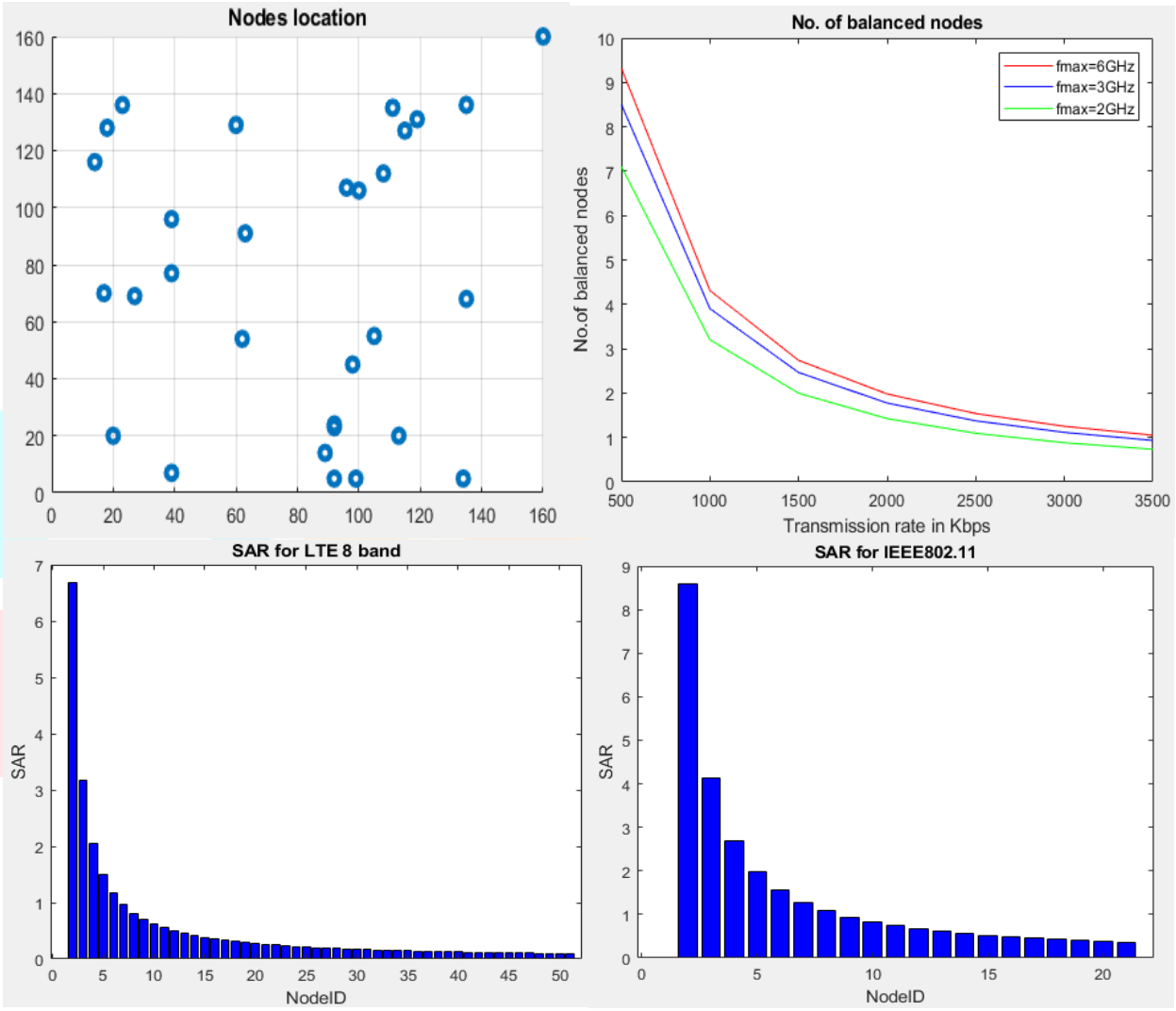
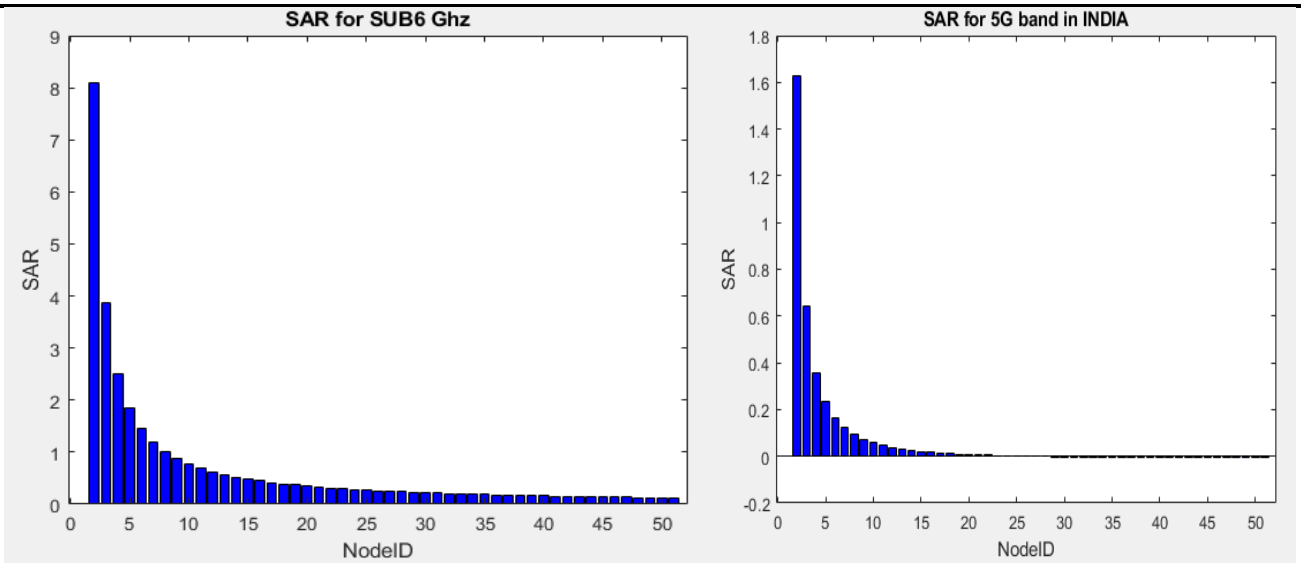



Figure 4 : in clockwise (a) D2D network (b) number of balanced node analysis (c) SAR for LTE8 band (d) SAR for IEEE802.11

The above results shows the simulation output observed on Matlab , figure (a) represents a random D2D network by considering n number of nodes , the eucledian distance is calculated & is used for analyis of SAR between a sender & the reciever node , since the network is random , by considering the coordinates of the node , the position of the node & further estimation is done.

Figure (b) represents the number of balanced nodes , by considering three different maximum frequencies at 2Ghz, 3Ghz & 4 Ghz & at different transmission rate in kbps we see that the transmission rate is inversely propotional to the number of balanced nodes required for the analysis , as the transmission rate increases , the number of nodes we require in the d2d communication also decrease.

Figure (e) (f) (g) (h) represents the SAR analysis done considering different frequency bands of operation like LTE8 band , IEEE802.11 band, SUB 6 Ghz & 5G band used in India respectively , maximum & minumum frequency of these bands is considered & we finally get the SAR value at different number of nodes , by this analysis we get a clear idea so as to consider the number of nodes in D2D to keep the SAR value within the safe limit .




(e) SAR for SUB6 Ghz (f) SAR for 5G frequency band in India

## CONCLUSION & FUTURE WORK

This paper is a review on increase in the concern of the traffic growth in the wireless communication and networks, this also speaks of the electromagnetic fields that is going to affect our ecosystem and has an impact on the humans. The paper also addresses the concerns that has to be taken immediately to protect humans from the exposure to the electromagnetic fields in the long term because we are growing towards higher frequency ranges, hence it speaks about SAR that is the specific absorption rate along with the concerns associated with it. In order to achieve this, the concept of D2D communication and an overview of D2D communication, its advantages and challenges has been discussed in detail along with the characteristics concerned to the specific absorption rate and analysis of it on networks including the concepts of multi hop path for the desired spectrum. The paper also discusses in detail the the implementation of D2D technology along with architecture and also how D2D communication plays a crucial role in 5G technology in resource allocation. Emphasis is also given on the measurement of SAR and how we can significantly reduce it as per the standard levels.

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