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ANALYSIS AND PERFORMANCE EVALUATION OF DEVICE-TO-DEVICE COMMUNICATION USING MULTIPLE INPUT MULTIPLE OUTPUT TECHNOLOGY

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ABSTRACT

Device-to-Device (D2D) communications is a term used to describe the technology that allows two devices to communicate with each other directly without using the Base Transceiver Station (BTS) or indirectly with the BTS. Device-to-device (D2D) communication plays a very significant role in the traditional cellular networks as it promises ultra-low latency for communication among users. Device-to-Device emerged as the key technology advances in mobile wireless communications. This paper analysed the performance metrics, using Multiple Input Multiple Output **(**MIMO) techniques for enhancing signal transmission in (D2D) communication. The system parameters Signal-to-Noise Ratio (SNR), Interference-to-Signal Ratio (ISR), Received Signal Strength Indicator (RSSI), distance and Capacity were analysed; using MIMO technique and comparing the signal flow across the different signal interference and probation delay. MATLAB/SIMULINK is used in simulating the different parameters in comparing the performances of the network. The MIMO technique enhances to a greater degree the signal propagation and path strength improvement over other traditional systems techniques, as a result of multi-path signal navigation improves signal reliability across paths with better fidelity. In the simulation results, increasing the number of antennas at the transmitter and the receiver end gave spatial diversity gain. Which results in a simultaneous increase in signal strength at the transmitter and receiver with a decrease in communicated interference.

KEYWORDS*:* D2D, MIMO, Interference, Signal-to-Noise Ratio, Propagation

INTRODUCTION

Cellular communication has grown comprehensively since the start of era where people can make or receive calls from almost anywhere. Cellular communication is supported with an infrastructure known as the cellular network (Fang et al., 2017, Zhuoming et al., 2019, Hakola et al., 2010 and Janis et al., 2019)) of Device-to-Device (D2D) in cellular wireless communication. D2D communication represents a new technology component which allows devices close to each other to communicate directly instead of relaying the signal through the Base Transceiver Station (BTS).

The advantages of D2D communications are: Offloading the cellular system, increasing the spectral efficiency, reduced battery consumption, increased data rate, robustness to infrastructure failures and thereby enabling new services. Some appealing applications of D2D communications can be: video streaming, online gaming, media downloading, peer to-peer file sharing (Palattella., et al., (2016), Xia et al., (2017), Fang et al., (2017) and Zhuoming et al., (2019)). Although D2D communications provide several benefits for local-area services in cellular networks, the main challenge about selection of communication mode is still a major challenge in wireless communication.

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D2D communications should be able to operate in various modes, to achieve the maximum system performance (Ioannou et al., (2020, 2021), Xing et al (2020) and Sarma et al., 2023).

Device-to-Device emerged as the key technology advances in mobile wireless communications. This paper analysed the performance metrics, using Multiple Input Multiple Output **(**MIMO) techniques for enhancing signal transmission in (D2D) communication. The system parameters Signal-to-Noise Ratio (SNR), Interference-to-Signal Ratio (ISR), Received Signal Strength Indicator (RSSI), distance and Capacity were analysed; using MIMO technique and comparing the signal flow across the different signal interference and probation delay. MATLAB/SIMULINK is used in simulating the different parameters in comparing the performances of the network. Device-to-device (D2D) communication plays a very significant role in the traditional cellular networks as it promises ultra-low latency for communication among users.

The remaining part of this paper is arranged as follow; Section 2 introduce the performance evaluation model, relating the system parameters. Section 3 Implementation of Multiple Input Multiple Output (MIMO) technique in D2D network, describing a communication network with Transmits (T_X) antenna and Receives (R_X) antenna and the scenario where Chanel state information (CSI) is at the transmitting and receiving end. Section 4 result presentation and discussion, section 5 is conclusions and 6 is reference

Performance Evaluation Model

System Performance parameters

In D2D communication, radio path of the D2D link can be either between the devices directly or it can be either through the BTS, which serves as a relay path.

For every link, different system parameters have to be taken into account separately (Hou & Chem 2020, Bahonar & Omidi 2021). For example, if the battery life of the wireless devices is the parameter of interest, we will need to determine the duration of transmitting time of the signal to the transmitting power of the device when communicating. But, if the channel capacity needs to be considered, then a comparison is made of the links connecting the different D2D (i.e. the distance between the communicating nodes either direct or through the BTS). To increase the overall performance of the connecting links, interference-to-signal ratio (ISR) is considered. The other system parameters that are of utmost importance are: Distance, Signal to noise ratio (SNR), Received signal strength indicator (RSSI), and link Capacity (Chataut and Akl, 2020, Phunchongharn, et al., 2013 and Nardini, et al., (2018)

Distance

In D2D wireless mobile communication, in order to calculate path loss, SNR, RSSI, the basic parameter required is distance between the two nodes CUEs. If the devices are outside the proximity region, indirect (relay) D2D communication can take place using the relay mode process. Distance of the links, either between devices or either between the device is needed for calculation to be compared and used for further reason, being selection of mode for every link. (Maghsudi and Stanczak., (2011 and 2013), Chapman et al., (2013) and Zhai et al. (2019)).

Signal to Noise Ratio

The Signal to Noise Ratio (SNR) is the ratio between the signal strength achieved by wireless connection and the noise introduce in the connection region. The SNR of a network needs to be as high as possible. Interference with the signal can reduce the signal strength to quite an extent. SNR of direct mode is defined as:

$$\partial_{direct} = \beta_d \frac{|h_d|^2}{N_o} \qquad (1)$$

Where: h_d is the channel coefficient between the two terminals D1 and D2

β_d is the energy coefficient

N_0 is the variance of Additive White Gaussian Noise (AWGN)

Relating equation (1) to the signal common SNR equation thus

$$SNR = 10log_{10} \frac{P - signal}{p - noise}$$

Where: P-signal is the power of the signal

P-noise is the power of the noise

For indirect mode, since BTS is acting as a relay the overall SNR for indirect mode at the receiving end is defined thus:

$$\partial_{indirect} = \frac{|h_2 G h_1|^2}{(|h_2 G|^2 + 1)N_0} \qquad (2)$$

The relay receives the signal from source, amplifies it with amplification factor *G* and forwards it to the destination. The gain factor *G* of relay to maximize the end-to-end signal to noise ratio in a 2 hops system is represented as:

$$G^2 = \frac{1}{\beta_1 |h_1|^2 + N_0} \qquad (3)$$

Substituting (2) in (3) leads to the overall SNR for indirect mode as:

$$\partial_{indirect} = \frac{\beta_1\beta_2}{\beta_1 + \beta_2 + 1} \qquad (4)$$

Where $\beta_1 = \frac{\varepsilon_1|h_2|^2}{N_0}$ is SNR between *D*1 and BTS, and $\beta_2 = \frac{\varepsilon_2|h_2|^2}{N_0}$is SNR between BTS and *D*2 is SNR between *D*1 and *D*2. ∂_{direct} is SNR between *D*1 and *D*2.

Interference to Signal Ratio (ISR)

The Interference to Signal Ratio (ISR) is the quotient between the averages received interference co-channel interference power and the average received modulated carrier power (Gopal & Velmurugan 2024, Rathod & Tanwar 2024 and Zhi et al., 2022). To calculate the ISR, we need to define δ_D *as the* Interference limited area (ILA) control parameter between devices. The δ_D-ILA is seen as the area in which the ISR from Cellular User Equipment (CUE) to *D*2D is greater than a threshold δ_D.
The constraint for δ_D-ILA is formulated as:

$$I_R = \frac{P_{1.C_{UE}D_2}}{P_{2.D_1D_2}} > \delta_D \qquad (5)$$

Where: I_R is the ISR from CUE
δ_D is calculated by the BTS when the D2D pair and CUE are known. It can also be expressed as shown below:

$$P_{S_1D_1D_2} = \left(\frac{d_{D_1B}}{d_{D_1D_2}}\right)^{\propto} P_{1}D_1B \qquad (6)$$

$$P_{1D_1B} = (\delta_B)P_{1,C_{UE}D_2} \qquad (7)$$

Replacing the above (eq. 5) in (7), $\delta_D$with a path-loss component *α* results in:

$$\delta_D = \left(\frac{d_{D_1B}}{d_{D_1D_2}}\right)^{\propto} \frac{1}{\delta_B} \qquad (8)$$

Assuming that the maximum acceptable ISR at BTS is δ_B. Then the approximate SINR at D_1using δ_B-ILA control parameter can be written as:

$$\partial_{\delta_D} = \frac{|h_{D_1D_2}|^2}{I_R\left|h_{C_{UE}D_2}\right|^2} + \frac{N_o}{P_{S_1D_1D_2}} \approx \frac{\left|h_{D_1D_2}\right|^2}{I_R\left|h_{C_{UE}D_2}\right|^2} = \frac{1}{\delta_D}\partial \qquad (9)$$

Hence it shows that the maximum ISR is limited to δ_D.

Received Signal Strength Indicator

RSSI (Receive Signal Strength Indicator) is the signal strength received at the receiver. Depending on the channel conditions (fading), RSSI tends to vary for every link due to different physical and radio properties of the link. The RSSI from a path anode *j* from node k due to path loss PL_i is given by:

$$P_{R_j} = P_{T_k} - P_{l_i} \qquad (10)$$

where:
P_{R_j}–Received power from j
P_{l_i} - Path loss at i
$P_{T_k}$is the transmitted power from D2D at *k.*
The power transmitted of the BTS is kept different from that of the power transmitted by the devices.

Path loss

Path loss is the attenuation (loss) in power density of an electromagnetic wave as it propagates through space. Path loss explains the signal loss between a transmitting and a receiving antenna as a function of the propagation distance, frequency, the height of BS antenna, the height of user equipment antenna and other parameters. We can calculate the path loss for urban wireless environments as follows:

$$PL_i = 69.55 + 26.16logf - 13.82logh_b + (44.9 - 655logh_b)logd - C_H \qquad (11)$$

Where: f represents the frequency of transmission in MHz
d represents the distance between two points in kilometres
$h_b$represents the height of base station antenna in metres
$C_H$represents the Antenna height correction factor

$$C_H = 0.8 + \left((1.11logf - 0.7)H_m\right) - 1.56logf \qquad (12)$$

Where:H_m stands for the height of mobile station antenna in Metres
f stands for the frequency of transmission in MHz.
For different D2D links, path loss is calculated for that particular channel according to the parameters of the link.

Implementation of MIMO technique to D2D

MIMO systems are implemented in many advanced technologies in the Fourth Generation (4G/5G) of wireless communication systems and LTE (Sama et al., 2023 and Gismalla et al., 2022). MIMO technology boosts the communication system capacity and to enhance the reliability of the communication link since it uses several diversity schemes beyond the spatial diversity. Fundamentals of MIMO system model is depicted in Figure 1. a communication system with N_T transmit antennas and N_R receives antenas

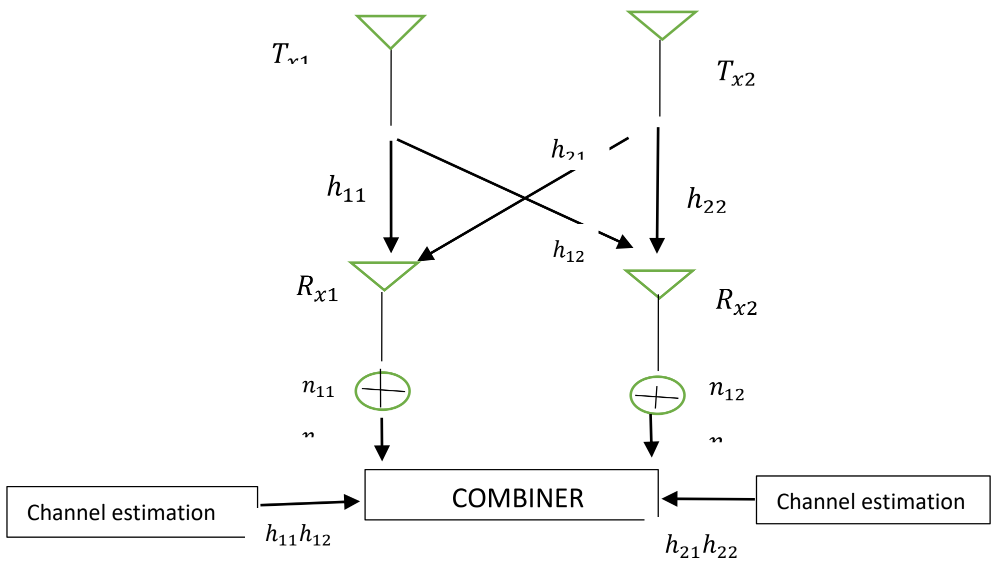

Figure 1: Stick MIMO configuration

Antennas T_{X1} . . . , T_{N_T} respectively send signals $x_1, . . . , x_{N_T}$ to receive antennas $R_{X_1}, . . . , R_{NR}$. Each receives antenna combines the incoming signals which coherently add up. The received signals at antennas Rx_1, , . . . , Rx_{N_R} are respectively denoted by $y_1, . . . , yN_R$.We express the received signal at antenna T_{X_q}; q = 1, . . . , N_R as:

$$y_p = \sum_{p=1}^{N_T} h_{qP} x_p + b_q \forall q = 1 \ldots . N_R, \forall p = 1, \ldots N_T \qquad (14)$$

The flat fading MIMO channel model is described by the input-output relationship as:

$$y = H * x + b \qquad (15)$$

Where: y transmitted signal
x receiver signal
b signal to noise ratio
h channel coefficient h is the ($N_R \times N_T$) complex channel matrix given by:

$$H = \begin{pmatrix} h_{11}h_{12} \ldots h_{1N_T} \\ h_{21}h_{22} \ldots h_{2N_T} \\ \cdot \\ \cdot \\ \cdot \\ h_{N_R1}h_{N_R2} \ldots h_{N_RN_T} \end{pmatrix} \qquad (16)$$

h_{pq}; $\forall p = 1, \ldots, N_T and \forall q = 1, \ldots, q_T$ is the complex channel gain which links transmit antenna Tx_p to receive antenna Rx_q.

$x = [x_1, \ldots x_{N_T}]^T$ is the $(N_T * 1)$ complex transmitted signal vector.

$y = [y_1, \ldots y_{N_T}]^T$ is the $(N_T * 1)$complex received signal vector.

$b = [b_1, \ldots, b_N]^T$ is the $(N_T * 1)$ complex additive noise signal vector.

Given a block time of length$L$, at time t, the transmitted signal is expressed as:

$$x = [x_1, \ldots x_{N_T}]^T; \quad t = 1, \ldots L$$

The input array signal $\boldsymbol{X}(N_T \times L)$ is given by:

$$X = \begin{pmatrix} X_1^{(1)} X_2^{(2)} \dots X_1^{(L)} \\ X_2^{(1)} X_2^{(2)} \dots X_2^{(L)} \\ . \\ . \\ . \\ X_{N_T}^{(1)} X_{N_T}^{(2)} \dots X_{N_T}^{(L)} \end{pmatrix} \qquad (17)$$

$y = [y_1, \dots y_{N_T}]^T$ is the $(N_T * 1)$complex received signal vector.

$$y = [y_1, \dots y_{N_T}]^T; \qquad t = 1, \dots L$$

The receive array signal $\boldsymbol{y}(N_T \times L)$ is given by:

$$y = \begin{pmatrix} y_1^{(1)} y_2^{(2)} \dots y_1^{(L)} \\ y_2^{(1)} y_2^{(2)} \dots y_2^{(L)} \\ . \\ . \\ . \\ y_{N_T}^{(1)} y_{N_T}^{(2)} \dots y_{N_T}^{(L)} \end{pmatrix} \qquad (18)$$

$b = [b_1, \dots, b_N]^T$is the $(N_T * 1)$ complex additive noise signal vector.

$$b = [b_1, \dots b_{N_T}]^T; \qquad t = 1, \dots L$$

The noise array signal $\boldsymbol{b}(N_T \times L)$ is given by:

$$b = \begin{pmatrix} b_1^{(1)} b_2^{(2)} \dots b_1^{(L)} \\ b_2^{(1)} b_2^{(2)} \dots b_2^{(L)} \\ . \\ . \\ . \\ b_{N_T}^{(1)} b_{N_T}^{(2)} \dots b_{N_T}^{(L)} \end{pmatrix} \qquad (19)$$

From equation (17) the expansion goes further: Since MIMO is in the space time coding mapping of the Alamouti's two branches of transmitting diversity can be represented by:

$$\begin{array}{c} \\ T_1 \\ T_2 \end{array} \begin{array}{c} TT+1 \\ \begin{pmatrix} X_1 - \overline{X_2} & \\ X_2 & \overline{X_1} \end{pmatrix} \end{array} \qquad (20)$$

The D2D receiver signal at the first slot of time $T_1$is;

$$\begin{bmatrix} y_1^1 \\ y_2^1 \end{bmatrix} = \begin{bmatrix} h_{11} h_{12} \\ h_{21} h_{22} \end{bmatrix} \begin{bmatrix} X_1 \\ X_2 \end{bmatrix} + \begin{bmatrix} n_{11} \\ n_{22} \end{bmatrix} \qquad (21)$$

y_1^1 is the receiver signal in the first time slot at receiver antenna 1.
y_2^1 is the receiver signal in the first time slot at receiver antenna 2.

$$\begin{bmatrix} y_2^2 \\ y_2^2 \end{bmatrix} = \begin{bmatrix} h_{11} h_{12} \\ h_{21} h_{22} \end{bmatrix} \begin{bmatrix} -\bar{X}_2 \\ \bar{X}_1 \end{bmatrix} + \begin{bmatrix} n_{21} \\ n_{22} \end{bmatrix} \qquad (22)$$

y_1^2 is the receiver signal in the second time slot at receiver antenna 1.
y_2^2 is the receiver signal in the second time slot at receiver antenna 2.
Taking the conjugate of both sides of equation (3.) and rearranging for X_1 and X_2 ie;

$$\bar{y}_1^2 = -\bar{h}_{11} X_2 + \bar{h}_{12} X_1$$
$$\bar{y}_2^2 = -\bar{h}_{21} X_2 + \bar{h}_{22} X_1$$

$$\begin{bmatrix} \bar{y}_1^2 \\ \bar{y}_2^2 \end{bmatrix} = \begin{bmatrix} \bar{h}_{12} & -\bar{h}_{11} \\ \bar{h}_{22} & -h_{21} \end{bmatrix} \begin{bmatrix} X_1 \\ X_2 \end{bmatrix} + \begin{bmatrix} \bar{n}_{21} \\ \bar{n}_{22} \end{bmatrix} \qquad (23)$$

Combining equations 22 and 23 the following is achieved;

$$\begin{bmatrix} y_1^1 \\ y_2^1 \\ \bar{y}_1^2 \\ \bar{y}_2^2 \end{bmatrix} = \begin{bmatrix} h_{11} h_{12} \\ h_{21} h_{22} \\ \bar{h}_{12} - \bar{h}_{11} \\ \bar{h}_{22} - \bar{h}_{21} \end{bmatrix} \begin{bmatrix} X_1 \\ X_2 \end{bmatrix} + \begin{bmatrix} n_{11} \\ n_{12} \\ \bar{n}_{21} \\ \bar{n}_{22} \end{bmatrix}$$

Further, $\begin{bmatrix} x_1 \\ x_2 \end{bmatrix}$ can be obtained thus;

The matrix in equation (23) can be written as;

$$y = Hx + n \qquad (24)$$

Removing the noise element or component

$$y = hx \quad \rightrightarrows \quad x = {}^{y}/_{h} \qquad (25)$$

The inverse of h.
Since it is not a square matrix, we compute the inverse using Hermitian matrix.

$$h^{-1} = (h^h h)^{-1}.h^h \qquad (26)$$

h^h is the Hermitian matrix of h.

$$[h^h.h] = \begin{bmatrix} \bar{h}_{11}\bar{h}_{21}h_{12}h_{22} \\ \bar{h}_{12}\bar{h}_{22}-h_{11}-h_{21} \end{bmatrix} \begin{bmatrix} h_{11}h_{12} \\ h_{21}h_{22} \\ \bar{h}_{12}-\bar{h}_{11} \\ -\bar{h}_{22}-\bar{h}_{21} \end{bmatrix} \qquad (27)$$

Therefore, $h^{-1} = h^h$ and hence $x = yh^h$
Hence, in the MIMO imploded matrix form is:

$$\begin{bmatrix} \tilde{x}_1 \\ \tilde{x}_2 \end{bmatrix} = \begin{bmatrix} \bar{h}_{11}\bar{h}_{21}h_{12}h_{22} \\ \bar{h}_{12}\bar{h}_{22}-h_{11}h_{21} \end{bmatrix} \begin{bmatrix} y_1^1 \\ y_2^1 \\ \bar{y}_1^2 \\ \bar{y}_2^2 \end{bmatrix} \qquad (28)$$

Where $\tilde{x}_1$ and $\tilde{x}_2$ are the estimate of the transmitted signal.
The continuous time delay MIMO channel model of the $N_T * N_R$MIMO channel H associated with time delayτ and noise signal $b(t)$ is expressed as:

$$y(t) = \int_{\tau} H(t,\tau)x(t,\tau) \; + b(t) \qquad (29)$$

$y(t)$ is the spatio-temporel output signal
$x(t)$ is the spatiotemporal input signal
$b(t)$ is the spatio-temporel noise signal
$(\cdot)^T$ Denotes the transpose operator
MIMO channel impulse response is evaluated according to the radio wave which propagates from the transmitter to the receiver. The MIMO channel model is determined based on the antenna configuration at both the transmitter and the receiver, antenna polarization, scatters, Physical models include both deterministic models and Geometry-based stochastic channel models (GSCMs) (Zhang et al., 2013) and (Gulati and Dandekar., 2014).
MIMO technologies boost the communication system capacity by enhancing the reliability of the communication link since it uses several diversity schemes beyond the spatial diversity. As in Figure 1 above with N_T transmit antennas and N_R receive antennas. describing a simple MIMO communication with multiple antennas at transmitting and receiving end of the node.

Features of D2D MIMO

Table 1: shows the features of D2D MIMO.

Feature	D2D MIMO
Main	Communication with multi antenna system
Purpose	MIMO capacity gain/ data rate increase
Advantage	Multiplexing gain/no interference
CSI	Perfect CSI required
Throughput	Higher through at high SNR

Signal Transmitted T_x–MIMO

Let $X_k(M_k \times 1)$, the transmit signal vector of user U_k; $\mathrm{k} = 1,\dots,\mathrm{K}$. Assuming that data streams associated to D2DU_k; $\mathrm{k} = 1,\dots,\mathrm{K}$ are zero mean white random vectors where:

$$E\{X_K X_K^*\} = I_{M_K}; \quad \forall K = 1,\dots,k \quad (30)$$

E denotes the expected value operator.
The complex channel matrix relating user Uk; $\mathrm{k} = 1,\dots,\mathrm{K}$ to the base station, $H_k$is of dimension $(N \times M_k)$. In presence of additive noise signal $b(N \times 1)$, the received signal
vector at the base station, $y(N \times 1)$ is expressed in the slow fading model by:

$$y = \sum_{k=1}^{K} H_K * X_K + b \qquad (31)$$

The noise signal vector is a zero mean white Gaussian variable with variance σ_b^2. The $T_x$scenario should satisfy two constraints: It should be as many receive antennas at the T_x as the total number of CUEs antennas.
Each D2D should have as many transmit antennas as the number of data streams.
The block of the transmitted signal for D2D MIMO should include a joint linear pre-coder and decoder. Linear pre-coders associated to users$U_1, \dots, U_k$; will be respectively denoted as $F_1, \dots F_k$. The received signal vector at the D2D is then expressed as:

$$y = \sum_{k=1}^{k} H_k . F_k . X_k + b \qquad (32)$$

An estimate of the transmitted signal vectors denoted by y_k; $\mathrm{k} = 1, \dots, \mathrm{K}$ are obtained by using the linear decoders $G_1, \dots, G_k$. The decoding process is such that:

$$y_k = G_k . y \qquad (33)$$

Where: y_k instantaneous SNR
G_k channel matrix y SNR

Signal Transmitted $\boldsymbol{R_x}$–MIMO

Assumes that K D2D are simultaneously receiving signals from the Next D2D. The transmitted signal vector$x(N \times 1)$is expressed as the sum of signals intended to users$U_1, \dots, U_k$:

$$x = \sum_{k=1}^{k} X_k \qquad (34)$$

The channel matrix between user U_k; $k = 1, \dots, K$ and the base station is denoted by $H_k(M_k \times N)$. At each user, received signal vector of dimension $(M_k \times 1)$; $k = 1, \dots, K$ is given by:

$$x_k = H_k . X + B_k ; \ \forall\, k = 1, \dots, k \ \ (35)$$

B_k; $k = 1, \dots, K$ is an additive noise signal vector of size $(M_k \times 1)$. Equation (35) could be also written;

$$x_k = H_k . X + B_k ; \ \ \forall\, k = 1, \dots, k$$

$$y_k = H_k . X_k + \sum_{j \neq k}^{k} \left(H_k * X_j \right) + B_k ; \ \ \forall\, k = 1, \dots, k \ (36)$$

Capacity region of MIMO with multiple antennas D2D

The capacity region could be obtained for the generalized case where the D2D has N antennas and usersU_k; $k = 1, \dots, K$is equipped with multiple antennas of number $M_k > 1$. An upper bound of the maximum achievable rate for user U_k is given by:

$$R_k = log_2 \left[\det \left(I_N + \frac{H_k . D_k . H_k^*}{N_o} \right) \right] ; \ \forall k = 1, \dots, k \ \ (37)$$

Where: $H_k(N \times M_k)$ links the N antennas to the M_k antenna user; $k = 1, \dots, K$.
$D_k(M_k \times M_k)$is a diagonal matrix formed by the power allocated at transmit antennas at user U_k.
The sum rate constraint of D2D-MIMO with multiple antennas is expressed as:

$$R_1 + \cdots + R_k \leq log_2 [(I_N + \sum_{k=1}^{k} \frac{H_k . D_k . H_k^*}{N_O})] \ \ (38)$$

Simulation Results

The simulation parameters as in Table 2. From equations (18 - 24,). In an environment, where the D2D can be relay through a base transceiver station or having a direct connection equation (11 and 12) with the other D2D is considered. The table described the: signal strength bandwidth for the data transfer across the communicating device, Non-Line of Sight (NLO) and Line of Sight (LOS) in equation etc. Once the simulation parameters are imputed, devices are simulated accordingly. The main parameters used in the simulation are defined in Table 2.

Table2: Parameters and values used for simulation

Parameters	Values
Bandwidth of data transfer	180kHz-10MHz
Beaming forming training time	0.28msec
Transmitting power/ half power beam width	10dBm and 20dBm
LOS and NLOS path loss	2.00 - 3.00 dB
Noise power	-174 – 20 dBm
Cell radius	5m
D2D user radius	1-3m
Number of transmitting Tx antennas	4
Number of receiving Rx antennas	4

Simulation Environment/Hardware Requirements

The software environment is detail as: Matlab version: 8.0.0.783 (R2012b). The laptop used has the following specifications: it has Microsoft Windows 10 as operating system. The RAM size is 8 GB, system rating are as: 64-bit operating system the processor is Intel (R) core i5 CPU @ 2.4 GHz

Performances of MIMO system

MIMO technology has improved the capacity of the communication link without the need to increase the transmission power. MIMO system capacity is mainly evaluated according to the following scenarios: spectral efficiency, Bits error rate, Signal-to-noise ratio, the used of multi-path and multiple antennas used etc.

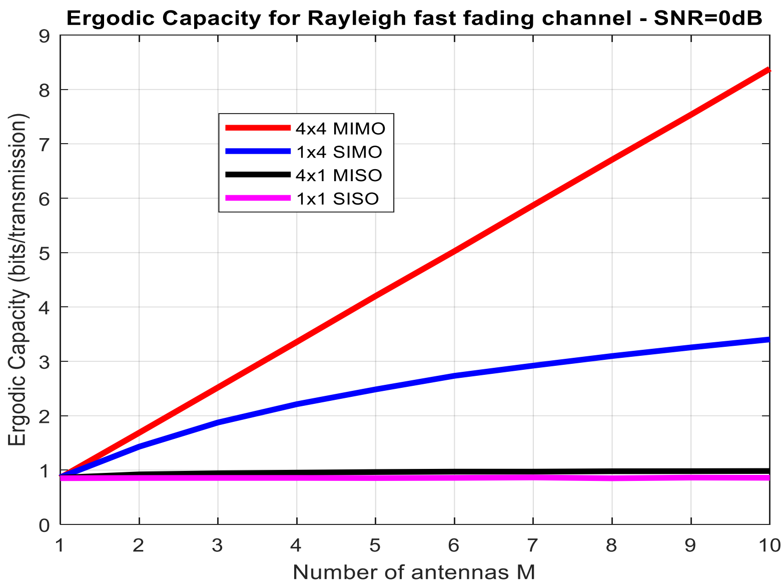

Figure 2: Ergodic Capacity (bits/Hz/s) with the numbers of transmitting antennas.

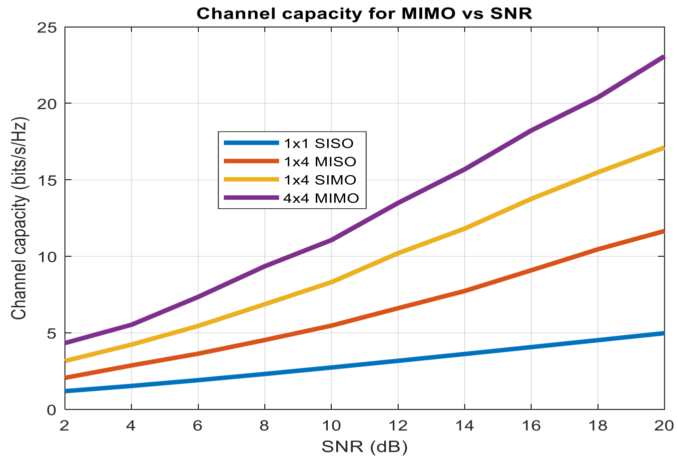

Figure 3: System capacity (bits/Hz/s) with SNR (dB)

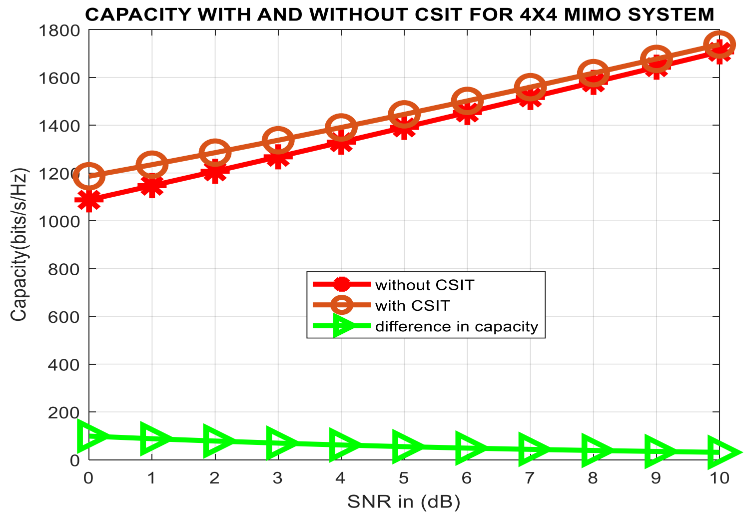

Figure 4: Capacity of system showing signal with CSIT and no CSIT.

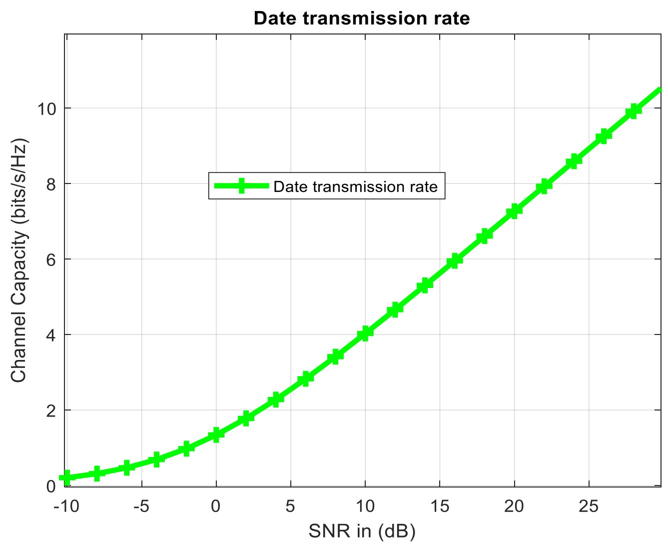

Figure 5: MIMO capacity (bits/Hz/s)

RESULTS DISCUSSION

Figure 2: shows the MIMO capacity across the network and comparing the signal flow across the different signal modes which are SISO, MISO, SIMO and MIMO, when compare in a D2D wireless network, the MIMO shows a greater signal propagated which is a significant improvement over other system. As a result, multi-path propagation phenomenon of signal can take different routes arriving the receiver with better fidelity compared to the other propagation techniques as earlier mention.

As seen in **Figure 3:** below, the other systems (SIMO, MISO and MIMO) have shown a significant improvement over the SISO system. Increasing the number of antennas either at the transmitter or the receiver gave spatial diversity gain. Even at a BER of $2\,x\,10^{-3}$, the MISO, SIMO and the MIMO systems perform approximately 10 dB better than the SISO system. By observing the slope of the curves, the remark is that for higher SNR, the gap will increase. Adding more transmitting antenna to the system gives the system more gain. Although the transmitted power may be halved or reduce. The MIMO system has about 10 dB better performance than the SIMO system at a SNR of 10^{-5}. As SNR is increased, the performance gap increased as well.

Figure 4: bellow shows the phenomenon where a system transmits signals through the MIMO system with CSIT and without CSIT. As the capacity of the system is being increase continuously, and AWGN also gradually added across, MIMO systems with CSIT perform better than systems without CSIT due to system diversity (multi-antennas). MIMO systems with CSIT as it can mitigate the effect created by path loss and interference, and maximizes the throughput. In MIMO systems, in case of relay network the base station estimates the CSI with the help of uplink pilot signals or feedback sent by the user (D2D) terminals. The received CSI at the base station is not uncontrollable and not perfect due to several environmental factors on the wireless channel. Although the base station does not receive perfect CSI, still the downlink performance of the base station largely upon the estimated CSI.

Figure 5: bellow shows that as the D2D network capacity continuous to increase, at the same ratio the AWGN also increases in the same proportion. It is simple that increasing one system parameter will automatically lead to the increase in the other factor of the system (signal-to-noise ratio). At higher SNR's, Capacity increases linearly with the rank of channel matrix. The performance with MIMO is better than other system. This is due to the array gain seen in MIMO case. Better performance of MIMO can be explained by the additional degrees of freedom available

CONCLUSION

In Comparing the BER curves from a MIMO channel with the BER curves obtained from a SIMO system in the multipath condition in mode selection D2D, the diversity gain from a MIMO channel is considered necessarily better in mode selection than the diversity gain provided by a SIMO channel. This is because to obtain the best diversity gain, only the dominant mode in a MIMO channel is used because of its multi-path signal flow; we can see an improvement of up to 1.5dB in the simulation curves obtained in Figure 2 and there is an increase in the capacity (b/s/Hz) of about 18 megabit per second in Figure 5 when compare with other traditional bits transfer methods, which is an added advantage to the mode selection process.

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