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Comparison of Modulation Schemes for Implementing Battery Deposit Service in LTE-A

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Abstract- **In this paper, a detailed comparison of modulation techniques is done for improving the quality of service of BDS, which is a technique based on cooperative device-to-device communication. Battery Deposit Service scheme allows users with higher battery level to carry traffic of users with lower battery level, thereby reducing the chances of user running out of battery early. This system can be realized in the form of a proximity service (ProSe) which will utilize device-to-device (D2D) communication architecture underlaying Long Term Evolution (LTE) technology. With the help of comparison of modulation techniques, it has been shown that 8-QAM serves to fulfill all the requirements of BDS system in an effective manner.**

Index Terms- **Cooperative Relaying, Battery Deposit Service, Quadrature Amplitude Modulation, Long Term Evolution, D2D communication**

I. INTRODUCTION

Smartphones have emerged into platforms with powerful computational capabilities that generate large amount of data. Smartphones have become an important part of our daily life and we use smartphones more frequently than we used desktop computers to stay connected on internet, reading news, playing games, browsing, watching video and staying connected with friends through social networking websites. On the other hand the smartphones have a strict energy budget and limited lifetime on a single charge. As the battery technology could not keep pace with smartphone technology, a short battery life has always been a major limiting factor for the utility of smartphones. In previous works [1] the Battery Deposit Service (BDS) scheme has been introduced as an application of Device to Device (D2D) technology underlying Long Term Evolution-Advance (LTE-A) network. The whole idea is based on *redistributing* the existing energy to increase usage time of smartphone battery.

Firstly, the notions of *valued battery lifetime, valueless battery lifetime* and *outage events* are explained. *Valued* battery lifetime is defined as the lifetime of battery of the smartphone when the user is active and does not have access to a power source [8]. Conversely, *valueless* battery lifetime is defined as the remaining battery lifetime of the smartphone after the usage period, when the user gets access to a power source. *Outage events* are instances when the user runs out of (valued) battery before his target usage time.Since the usage patterns of the users varies, the value of their batteries also varies. The BDS system takes advantage of the wide range of battery value created by this diversity of usage. By enabling cooperation, the users are allowed to spend their valueless battery to save someone else’s valued battery, reducing the probability of their outage events and increasing the probability of survival of user’s battery as a result. Advance the mechanism being used in BDS system for “distributing” battery, is device-to-device cooperative relay underlaying LTE-A networks. This mechanism will help to create direct links between cellular users. A licensed spectrum for D2D operation is proposed in 3GPP release 12 work item [3]. This will benefit in controlling of D2D operation. As a result, the bandwidth and QoS of the communications can be guaranteed. This can also increase system security by making D2D operation transparent to the users. One main property of a D2D connection which is of utmost importance for the proposed system is that it consumes significantly less power than a cellular link. This is because on the uplink, the phone needs to cover a much shorter distance to reach a D2D neighbour than to reach a base station. The main component of the signal energy loss over the wireless channel is the distance related path loss. Hence a much lesser signal energy loss is seen with this technology which will in turn minimize the requirement of battery power.

In this paper a comparison of different modulation schemes has been done with respect to BDS. In previous work, modulation scheme used was 16-QAM. The results of comparison shows that for BDS, 8-QAM serves to be a much better option considering the requirements of low data rate and symbol error rate and a much greater battery usage time .

The rest of the paper is organized as follows. In section II, a summary of BDS scheme is given, outlining its merits, challenges, and progress in standards. Section III discusses the various QAM modulation schemes. The various parameters for performance of BDS are given in section IV. Section V gives details of obtained simulation results. The paper is finally concluded in section VI.

II. BATTERY DEPOSIT SERVICE

BDS is a technique for battery optimization of smartphones. It is based on reduction in energy consumed by communication over network. This will be achieved by utilizing cooperative device-to-device communication is shown in Fig.1. The system is designed to allow users with higher battery level to carry traffic of users with lower battery level, thereby reducing the chances of user running out of battery early. It is proposed to be implemented in form of a proximity service (ProSe) [7] under D2D communication architecture underlying LTE-A technology.

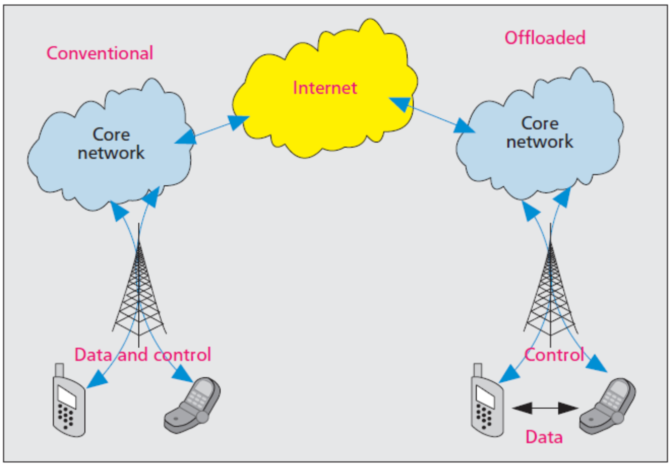

Fig.1 A conventional cellular and D2D network scenario

BDS addresses the issue of increasing smartphones' battery life by reducing power consumption in network communications. This approach is made effective by *redistributing* the existing energy in network to increase usage time of battery power.

In [9], the notions of valued battery and valueless battery have been introduced as the amount of the smartphone battery when the user is active without having any access to power source or the amount smartphone battery remaining after the usage period, when the user have access to some power source, respectively. A method of developing cooperation between users is followed which allows them to spend their valueless battery power to save somebody else's valued battery power, thereby decreasing their probability of outage. The device-to-device cooperative relay underlying cellular networks is the physical mechanism used for "distributing" battery. This scheme helps in increasing the quantity of valued battery power in the network, henceforth reducing the cases of UEs running out of battery early. The concepts of depositing and withdrawing the battery have been used to explain the fact that the benefits of helpers need not to be reciprocal or immediate. This means that a user who receives help can repay, at a later time, to some other user than the one who helped him. In this way BDS will be beneficial to large number of users.

III. QUADRATURE AMPLITUDE MODULATION

Quadrature Amplitude Modulation (QAM) conveys data by changing some aspect of a carrier signal, or the carrier wave, (usually a sinusoid) in response to a data signal. In the case of QAM, the amplitude of two waves, 90° out-of-phase with each other (in quadrature) are changed (*modulated* or *keyed*) to represent the data signal. Amplitude modulating two carriers in quadrature can be equivalently viewed as both amplitude modulating and phase modulating a single carrier.

As in many digital modulation schemes, the constellation diagram is useful for QAM. In QAM, the constellation points are usually arranged in a square grid with equal vertical and horizontal spacing, although other configurations are possible (e.g. Cross-QAM). Since in digital telecommunications the data are usually binary, the number of points in the grid is usually a power of 2 (2, 4, 8, …). Since QAM is usually square, some of these are rare—the most common forms are 16-QAM, 64-QAM and 256-QAM. By moving to a higher-order constellation, it is possible to transmit more bits per symbol. However, if the mean energy of the constellation is to remain the same (by way of making a fair comparison), the points must be closer together and are thus more susceptible to noise and other corruption; this results in a higher bit error rate and so higher-order QAM can deliver more data less reliably than lower-order QAM, for constant mean constellation energy. Using higher-order QAM without increasing the bit error rate requires a higher signal-to-noise ratio (SNR) by increasing signal energy, reducing noise, or both.

If data-rates beyond those offered by 8-PSK are required, it is more usual to move to QAM since it achieves a greater distance between adjacent points in the I-Q plane by distributing the points more evenly. The complicating factor is that the points are no longer all the same amplitude and so the demodulator must now correctly detect both phase and amplitude, rather than just phase.

There are two types of QAM: Rectangular QAM and Non-rectangular QAM. These are discussed below:

A) Rectangular QAM

Figure 2 shows constellation Diagram for Rectangular 16 QAM.Rectangular constellations are, in general, sub-optimal in the sense that they do not maximally space the constellation points for a given energy. However, they have the considerable advantage that they may be easily transmitted as two pulse amplitude modulation (PAM) signals on quadrature carriers, and can be easily demodulated. The non-rectangular constellations, dealt with below, achieve marginally better bit-error rate (BER) but are harder to modulate and demodulate.

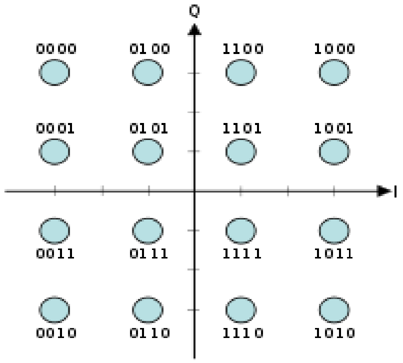

Fig.2 Constellation diagram for rectangular 16 QAM

B) Non-rectangular QAM

Figure 3 shows diagram of circular QAM constellation for 16-QAM. The The 16-QAM constellation is suboptimal although the optimal one may be constructed along the same lines as the 8-QAM constellation. The circular constellation highlights the relationship between QAM and PSK. Other orders of constellation may be constructed along similar (or very different) lines. It is consequently hard to establish expressions for the error rates of non-rectangular QAM since it necessarily depends on the constellation. Nevertheless, an obvious upper bound to the rate is related to the minimum Euclidean distance of the constellation (the shortest straight-line distance between two points) that's why rectangular QAM has been used in this paper.

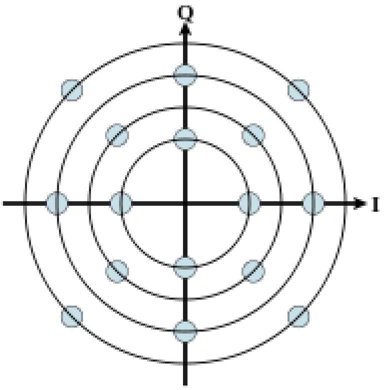

Fig.3 Constellation diagram for Non-rectangular 16 QAM

IV. PERFORMANCE EVALUATION FRAMEWORK

The performance of the proposed system is evaluated on the basis of following parameters [4] & [5]:

A) *Power consumption:* In LTE, a UE's uplink transmit power is controlled by Eq (1).The formula is based on path loss between the UE and either the relay or eNodeB [4]

$$Transmit\ Power\ P_{t_0}\ (in\ dB) = -K - PG + E + L' - G - H + C + Path\ Loss(in\ dB) \quad \textbf{(1)}$$

Where, the various parameters are as enlisted in Table 1. The path loss can be calculated by using channel model. In addition to this, after transfer of every data burst, the eNodeB allows UE to stay in RRC CONNECTED state for some more time. In this state, the UE consumes appreciable amount of energy than that in RRC IDLE state. The duration during which the UE stays in the RRC CONNECTED state is decided by the eNodeB. After modeling this factor as well as the other circuitry-related energy consumption, it is added to all transmissions as a constant component (both D2D and regular uplink).

B) *Usage time:* Here the usage time of a UE is the time duration from the start of the simulation to the instant when the UE runs out of battery power. It can be estimated as below:

$$U = \sigma_t * \sqrt{2\pi} * \left\{ e^{\frac{-\mu_t^2}{2\sigma_t^2}} - e^{\frac{(t-\mu_t)^2}{2\sigma_t{}^2}} + \left[t - \frac{t-\mu_t}{F\left(\frac{t-\mu_t}{\sigma_t}\right)} \right] \right\} \quad \textbf{(2)}$$

where, F(x) = Gaussian CDF of x

$$F(x|\mu,\sigma) = \frac{1}{\sigma\sqrt{2\pi}} \int_{-\infty}^{x} e^{\frac{(t-\mu)2}{2\sigma 2\,2}}\, dt \quad \textbf{(3)}$$

and, σ_t = variance of total time involved in BDS

μ_t = mean total time involved in BDS

C) *Probability of outage:* It is defined as the probability of the cellular users running out of their battery power before the target usage time. It is given by:

$$P_{outage} = 1 - F\left(\frac{t-\mu_t}{\sigma_t}\right) \quad \textbf{(4)}$$

Where, F(x) = Gaussian CDF of x as described by Eq. (3)

V. SIMULATION PARAMETERS

The simulation parameters are summarized in Table 1

TABLE 1
PARAMETERS FOR SIMULATION OF BDS

Parameters	**Values**
Cell Radius	500m
No. of UEs	500
Mean data inter-arrival time *(Barr)*	30s
Mean burst size *(Bmean)*	7800 bytes
Speed	0.1-3m/s
Pause duration	0-300s
Walk duration	30-300s
Path loss compensation factor (α)	0.8
Constant energy cost factor	15mJ
Communication battery budget	300J
Base power (*Po)*	69dBm
Maximum transmit power *(T)*	24dBm
Modulation order QAM 8	8
Modulation order QAM 16	16
Modulation order QAM 64	64
Code rate	1/3
Carrier frequency	2GHz
No. of Resource Blocks/subframe (*NRB*)	100
eNode B antenna height	25m
UE antenna height	1.5m
No. of walls for indoor NLOS	1
Cooperation threshold $\gamma 1,\gamma 2$	0.3,0.3
Cooperation path loss threshold	110dB
Cooperation radius	30m
SNR (Eb/No) *(E)*	3.3dB
Noise Margin *(K)*	3dB
Processing Gain *(PG)*	27.95db
Handoff gain *(H)*	5dB
Log Normal fade margin *(L')*	11.3dB
Cell Antenna gain *(G)*	10dB
Cable Loss *(C)*	2dB

VI SIMULATION RESULTS

The proposed model has been implemented as an event-driven simulation in MATLAB environment. The simulation is initialized with UEs located at uniformly random locations within a hexagonal cell and having a random battery level. In this paper, the Modulation and Coding Scheme (MCS) values have been used. For each MCS s, there is corresponding required SNRs to achieve some predetermined packet error rate (e.g. 10%). These SNR requirements are usually obtained by simulation. In this work, we will use the MCS values, and the corresponding required SNR, from Table 2, introduced in [6] with respect to BDS. In previous work, modulation scheme used was 16-QAM. The results of comparison shows that for BDS, 8-QAM serves to be a much better option considering the requirements of low data rate and symbol error rate and a much greater battery usage time.

TABLE 2
MODULATION AND CODING SCHEMES

Modulation	**Code Rate**	**SNR(dB)**	**Efficiency (bits/symbol)**
8 QAM	1/2	2.88	1.00
8QAM	3/4	5.74	1.50
16QAM	1/2	8.79	2.00
16QAM	3/4	12.22	3.00
64 QAM	2/3	15.88	4.00
64QAM	3/4	17.50	4.50

Figure 4 shows the plot of the Symbol Error Probabilities of 8, 16 and 64 QAMs for both theoretical values and values obtained from simulation. The graph shows that the Symbol error Rate (SER) increases with increase in modulation order. Thus 8-QAM is having least SER.

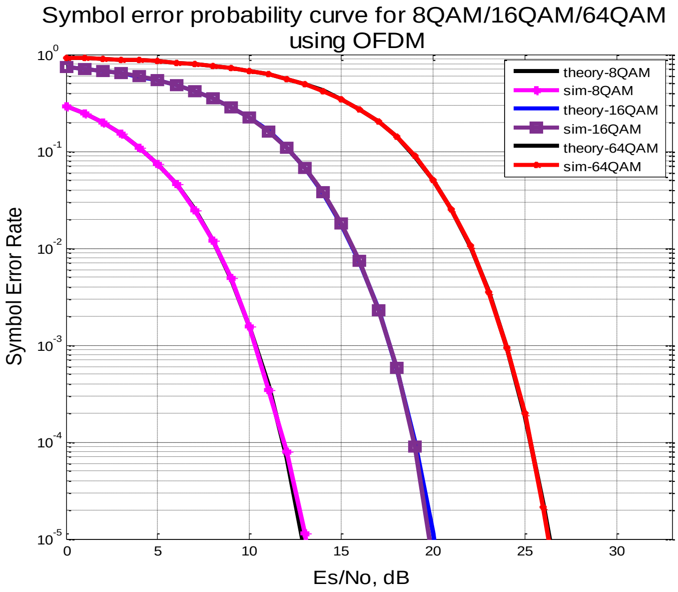

Fig.4 Symbol Error Probability curve for 8QAM/16QAM/64QAM

Figure 5 shows the plot of the Effect of Modulation Schemes on Transmission Power for both theoretical values and practicals values obtained from simulation. The graph shows that 8 QAM takes less transmission power as compared to 16 QAM and 64 QAM in D2D system and UE system.

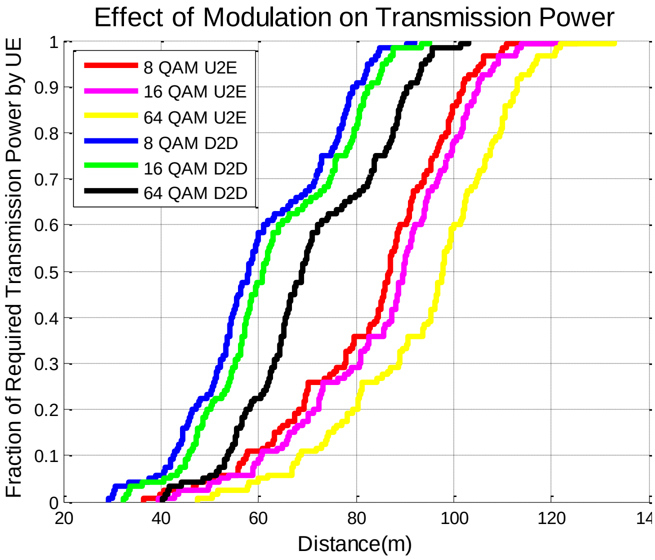

Fig.5 Plot of the Effect of Different Modulation Schemes on Transmission Power

Figure 6 shows the plot of the Battery usage time with different Modulation Schemes. The graph shows that the 8-QAM has greater Battery Usage Time than 16QAM and 64QAM.

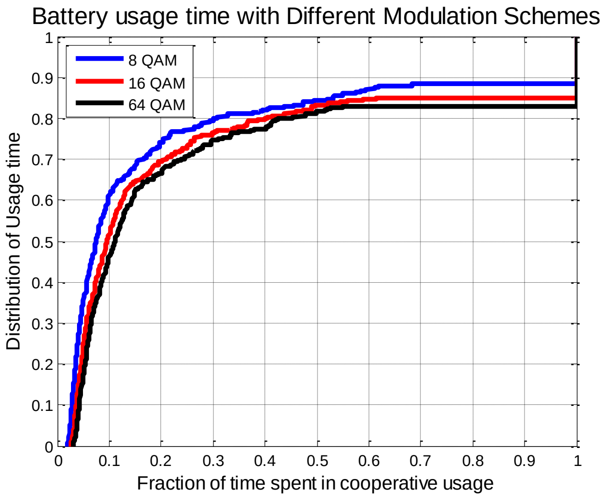

Fig.6 Plot of Battery Usage Time with Different Modulation Schemes

Figure 7 shows the plot of the Probability of Survival with Different Modulation Schemes. The graph shows that the Probability of Survival increases with decreases in modulation order. Thus 8QAM is having more Probability of survival.

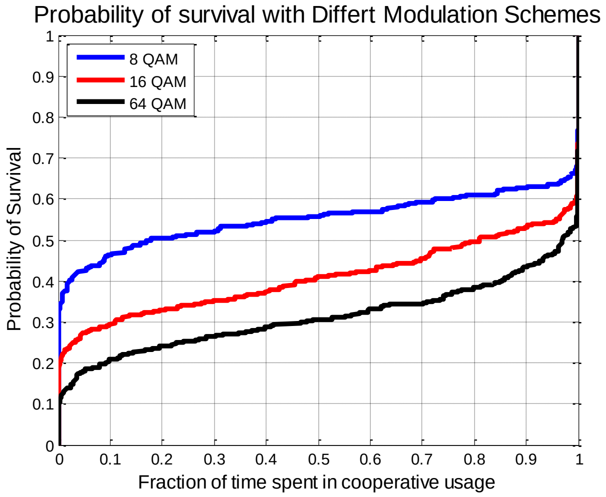

Fig.7 Plot of Probability of Survival with Different Modulation Schemes

VII CONCLUSION

In this paper we have done comparison of modulation schemes to be used for a D2D cooperative system, the Battery Deposit Service. The comparison has been done between the 8-QAM, 16-QAM and 64-QAM. From the analysis of all three types of modulations it is clear that 8-QAM has minimum data rate as well as less Symbol error Rate. It is thus verified from the obtained results that, using 8-QAM modulation scheme will further reduce data rate, thereby reducing the battery usage and hence will increase the overall efficiency of the system.

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