Smart Utilization LTE-UMTS Spectrum in Smart Grids for Communication

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Abstract—The paper focuses on the utilization of LTE-UMTS resources for communication or calls within Smart Grids to relay metering information or other data required. The LTE resource blocks (RBs) or UMTS codes are assigned to Smart Grid (SG) calls when they arrive in real time. The SG network relies on dynamic servers (mobiles or workstations) to store information sent to them. In this paper, each server will account for metering loads of five nearby meters. The proposed scheme aims to reduce the loading of the LTE-UMTS interface at the base station (BS) to increase call capacity. The proposed scheme is compared with related articles in literature in real time conditions. The calls (information) sent using LTE-UMTS provide fault detection and fast recovery, the server is usually serving five nearby domestic users. The metering information at servers will be available to domestic users and the electricity providers both. The result shows that using mobiles and PCs as servers reduces the load of BS and handle significantly larger number of SGs calls.

Index Terms— LTE, Smart Grids, power generation, smart meter.

1 INTRODUCTION

The current advancement of the power transmission using smart grids (SGs) makes them fully automated and interconnected medium voltage level electrical networks. These SGs provides operation of complex power grids in a safe and reliable way, with remote monitoring and control applications. This requires exchange of measurement data in real time. With the expansion of SGs the exchange of information critical for protection is massive and might need urgent attention which requires a communication technology that is fast and reliable too. There are many wireless technologies available like cognitive radio networks (CRNs), LTE and 3GPP release etc. The CRNs however is an unlicensed technology which suffers from lower quality of service (QoS) and high latency problems. LTE and 3GPP releases is a promising licensed technology which addresses issues of QoS and latency, one of the technologies which can address all these issues[1-2]. Utilization of LTE existing networks reduces the cost of operation and expansion which will be needed to implement communication network for SGs. Some work is available in literature to ascertain the viability of LTE as a communication technology for SG applications. For applications related to distributed automation LTE 3GPP release 8 is used in [3] and encourages the use of LTE for SGs. The paper in [4] uses ns-3 simulator, which simulates smart metering and remote control applications traffic. This traffic is sent over an LTE network handling radio network load also. The LTE network handles calls while maintaining their QoS. It has been found that the QoS (Quality of Service) management of LTE is strongly recommended in order to meet the desired time deadline[5]. In [6], a comparison between LTE Time Division Duplex (TDD) and Frequency Division Duplex (FDD) when used for smart grid communications is presented, and FDD is shown to lead to better uplink performance in terms of latency. However, FDD was shown to be control channel limited for small infrequent packets. In [7], this problem is addressed by proposing contention based random access over orthogonal frequency division multiple access (OFDMA) using any available free cellular spectrum. A novel Random access for distribution automation (RADA) is proposed in [8] to the contention with better support to distribution automation (DA) services with minimum degradation in handling of LTE subscriber services. A Lotka-Volterra (LV) resource allocation scheme is defined in [9], which modelled each class of traffic as a species and they try for available LTE resources. The constraints are also placed on service classes for bringing fairness. The use of LTE radio resource management is investigated in [10] for automatic meter reading in regions of advance meter infrastructures. The proposed scheme can be used for both methods of transmission, from smart metres to base station (BS) or for transmission of aggregated data at aggregators to the BSs. The author of paper [11] uses a hybrid of ZigBee on unlicensed 2.4 GHz and LTE networks. This hybrid provides more spectrums to LTE operation due to the transmission of the meter to meter information on ZigBee network using low power. This paper proposes an assignment scheme for handling the SGs traffic (SGT) and radio traffic (RT) on a LTE based network. The LTE based network uses two interfaces to handle both kinds of traffic. The proposed scheme also uses mobile or workstations as servers to store the metering or periodic data of meters.

The remainder of the paper is organized as follows. The system model and network parameters are given in section 2. In section 3, the proposed scheme is explained. Simulation and results are given in section 4. Finally, conclusions are given in section 5.

2 SYSTEM MODEL AND PARAMETERS

The system model consists of a BS equipped with two interfaces LTE_{int} and $UMTS_{\text{int}}$ which are handling both SGT and RT. The mobile or workstations acting as server can be applied for network based in urban areas where more number of RT users is available. The metering information or periodic updates to these mobiles or workstations in the same area can be sent in bulk or sequentially depending upon available spectrum. In rural areas, the number of RT users are less. In particular users, requiring higher speed or in other words the users competing for LTE interface are less. The metering information in rural areas than can be sent directly using LTE_{int}.

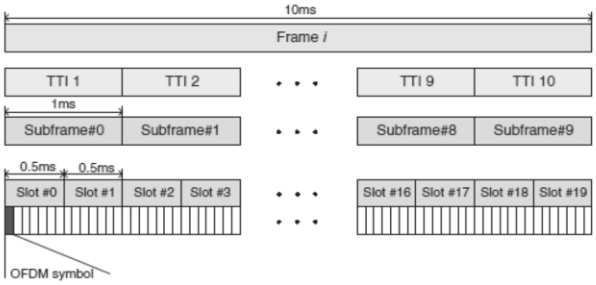

Fig. 1 A LTE PHY frame structure.

The LTE_{int} has 10 subframes in the time domain and two slots area available in each subframe. With every subframe 14 OFDM symbols can be carried as shown in Fig. 1. In frequency domain, 12 subcarriers are available in a subchannel. Number of subchannels depends upon bandwidth spectrum e.g, for a 3MHz spectrum the number of subchannels are 15. The relation between channel bandwidth and number of subchannels is given in Table 1 [16].

The transmission unit for a MS is defined by resource block (RB) within a subframe(for time)and a subchannel (for frequency)for LTE interface. The LTE interface uses spatial multiplexing with four antennas and the eNodeB for every channel pilot symbol is used as the individual reference signal symbol.

For multiuser access in OFDMA, a subframe RBs can be allocated to different MSs. For single user access in OFDM, the RMs of the subframe can be allocated to one MS, they cannot be allocated to different MSs [12-15]. For LTE using OFDMA, a MS will be allocated at least one RB and in the same subframe duration different MSs can use number of RBs allocated to them by eNodeB.

Table I. Total number of resource blocks (RBs) used within a subframe [16].

Channel bandwidth (MHz)	Number of RBs within a subframe time
1.4	6
3	15
5	25
10	50
15	75
20	100

The offered total data rate of the downlink a PHY frame of LTE is given by

$$R_{DL} = (N_{RB}(N_{NSC} \times N_{NSS} \times N_{bit}^{AMC})) \times N_{TTI} \qquad (1)$$

where

N_{RB}: denotes the allowed number of RBs within a subframe time.

N_{NSC}: denotes the subcarriers in a subchannel.

N_{NSS}: denotes the subframe OFDM symbols

N_{bit}^{AMC}: denotes bits in a symbol.

N_{TTI}: LTE PHY frame transmission time interval (*TTI*).

N_{bit}^{AMC} values with different modulation schemes is given in Table II [16].

The different modulation schemes are used for different location of RT and SGT.

The UMTS interface is equipped with orthogonal variable spreading factor codes (OVSF) which spreads in both time and frequency domain. The $UMTS_{\text{int}}$ is used for handling RT and for sending periodic updates of SGT. The $UMTS_{\text{int}}$ is having a code tree of layer L with total capacity of code tree $2^{L-1}R, L = 9$.

Table II. Number of bits per symbol and data rate of a resource block supported by different adaptive modulation and codings in a PHY frame[16].

Modulation	Bits/Symbol	One RB (Kbps)	Antenna
QPSK-1/2	1	144	Single
16QAM-1/2	2	288	Single
16QAM-3/4	3	432	Single
64QAM-1	6	864	Single
64QAM-1	12	1728	2X2 MIMO
64QAM-1	24	3456	4X4 MIMO

3 PROPOSED SCHEME

The proposed scheme for RT and SGT uses LTE_{int} or $UMTS_{\text{int}}$ depending upon the arrival of call request.

3.1 RT Request

For a RT voice call of rate $2^{l-1}R, 1 \leq l \leq L$.

i. Search the vacant code in layer l of rate $2^{l-1}R$, using CFA scheme define in [17].
ii. Assign a vacant code.
iii. If no vacant code available of rate available block the call.

For a RT data call of rate $2^{l-1}R, 1 \leq l \leq L$. The algorithm assigns RBs depending upon its location in the cell. For example, if 3MHz channel bandwidth (BW) is used by LTE system and it contains 150 RBs in one frame of PHY. Then the data rate of a RB using QPSK as AMC modulation scheme is calculated as

Rate_{RB}=12subcarriers × 12 symbols × 2bits/symbol × 10^3

= 288 Kbps

In a similar way, the offered data rate of a RB for every AMC modulation scheme can be determined as given in Table II. Consider a call of rate 8R arrives, the number of RBs(n_{RB}) required by it depends upon its location in cell.

i. Closer to BS, AMC scheme used 64QAM and $n_{RB} = \frac{8.144}{864} = 1.33 \cong 1$.
ii. Distance closer (a), AMC scheme used 16QAM, $n_{RB} = \frac{8.144}{288} = 4$.
iii. Distance closer (b), AMC scheme used QPSK, $n_{RB} = \frac{8.144}{144} = 8$.

iv. Closer to end of cell, AMC scheme used is BPSK, $UMTS_{int}$ is preferred else reject the request.

The system can assign the required RBs still it is preferred to set a maximum limit on number of RBs that can be assigned denoted by n_{RB}^{max}=4. If $n_{RB} \leq n_{RB}^{max}$, handle RT using LTE_{int} otherwise block it.

3.2 SGT Request

The SGT can be broadly divided into three types:

i. Metering information one hop.

The metering one hop messages are small data messages or data calls, which can be sent using $UMTS_{int}$. These messages usually contain meter details of power utilization by a home user in past one hour and are sent to its server (close by neighbour). They are treated as voice calls, if blocked retry for spectrum access after waiting for some time.

ii. Metering information from Mobile servers or work stations to BS.

This is collection of metering information of five or more domestic users in close vicinity to each other and requires high speed transmission. If sent with delay or lower QoS, requires headers which increases data load on the network. In this paper, they are considered as LTE data calls.

iii. Periodic messages about status of grid.

These messages are usually sent from one sensor to another for scheduling and messages informing about faults. The periodic messages are forwarded from one sensor to another. These messages contain small data and in peak hour can be discarded to reduce load on BS, if same as previous periodic message. A fault in a power distribution unit requires immediate attention and are handled using LTE_{int}.

4 RESULTS AND SIMULATIONS

To test the performance of the proposed scheme (LTE-UMTS) is compared with other schemes RADA [8] and LAA [11] for blocking probability and delay of SGT. The schemes are compared for two different traffic distributions:

i. Peak traffic distribution of RT.

ii. Low traffic distribution of RT.

In peak traffic distribution scenario RT=70% and SGT=30%, periodic message are discarded when they are similar to previous messages, it increases complexity due to more computation. For low traffic distribution RT=20% and SGT=80%. The arrival of both type of calls RT and SGT are assumed to be Poisson's distributed and the departure of calls is assumed to be exponentially distributed in interval (0,4] minutes. The result in Fig. 2(a) compares the blocking probability when RT arrival is higher and SGT lower, LTE-UMTS provides minimum blocking probability as it discarded periodic messages and stores metering information in MSs and workstation which are sent together as one data call. For the result in Fig. 2(b) RT arrival is low and SGT higher, LTE-UMTS provides blocking probability comparable to LAA and RADA, the network is handling only SGT calls which comprises periodic messages in higher frequency. The result in Fig. 2(c) and (d) compares the SGT delay incurred, it's due the reason the SGT sent its request again after waiting for sometimes and LTE-UMTS scheme calls needs minimum. In LTE-UMTS, the periodic messages

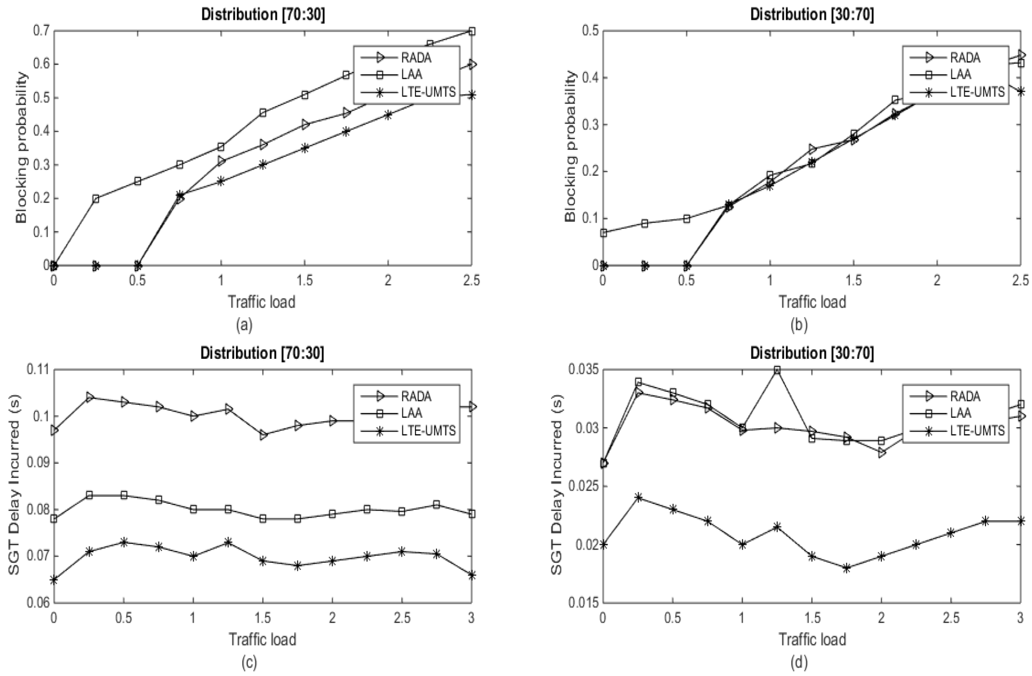

Fig.2 Comparison of blocking probability for distribution (a) [70:30], (b) [30:70] and SGT Delay incurred with increased traffic load (c) [70:30], (d) [30:70]

are discarded which leads to more spectrum availability.

5 .CONCLUSION

For efficient management of SGs, communication technologies like LTE, CRNs etc play an integral role. Utilization of these technologies will play an important role for control and operation of future SGs providing electrical transmission for domestic use. This paper uses LTE-UMTS cellular communication network for handling SGTs in presence of RTs efficiently. The MSs also acted as a server which reduces load on BS. The blocking probability of SGT and RT is relatively low as compared to other schemes. The completion time of SGT also reduces. The work in future can be done to find the share of revenue for storing metering information to MSs and workstations usually in neighbourhood. The periodic messages forwarding also increases SGT, work can be done to reduce this traffic.

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