An M2M Access Management Scheme for Electrical Vehicles

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***Abstract*— M2M communications have recently been introduced in smart grid and vehicular networking environments. Its principles can improve electrical vehicular networking while offering two-way communication between Electric Vehicles (EVs) and Electric Vehicle Supply Equipment (EVSEs). In this paper, we first study the impact of a very large number of connected EVs when attempting to use the random access in LTE-Advanced to communicate with the grid. Second, we propose an effective solution for avoiding congestion on the random access channel of LTE-Advanced for massive EV-2-EVSE communications. In this solution, we differentiate between two classes of service of EVs communications, giving priority to charging demands over other types of messages lower priority messages (promotions, subscriptions, mechanical checks, etc.). Finally, we propose an efficient admission control mechanism to manage EVs M2M traffic on LTE-Advanced and to provide QoS to charging demand messages in terms of strict delay to avoid both a long latency of EV users and a network overload in high offered load conditions.**

Keywords*— *Electric vehicle, broadcast, charging process, electrical vehicle supply equipment, LTE-Advanced;

I. Introduction

Experts expect energy production and distribution to be soon more localized in the smart grid, which will require much more information exchange between the involved entities. In order for this to be possible, an extensive use of Machine-to-Machine (M2M) communications using fixed and/or wireless networks such as Long Term Evolution (LTE) is required. The introduction of Electric Vehicles (EVs) would also need the network to become "smarter". The convergence of the connected vehicle with the EV is a good example to motivate the need of LTE technology. The connected vehicle may require to be connected to the network access all day, i.e., to the OEM for many reasons, as for example for mechanical checking.

Nevertheless, the deployment of a huge number of connected-EVs [1-2] could be an enormous burden on the network provider. If connected-EVs really become the vehicle of choice for the future, around one billion M2M communication units would be necessary in the Organization for Economic Cooperation and Development (OECD) region to coordinate charging these EVs. Wireless technologies must be engineered to face this challenge and to provide a reliable M2M communications even on high density of EVs-2-EVSEs communications conditions and the rise of M2M connections as shown in Cisco study Research M2M connections forecast (2016–2021) which would reach 1.1 Billions by 2017.

Particularly, LTE-Advanced [3,4,5], is envisaged to play a central role in interconnecting machines. Since LTE-Advanced evolves from LTE, it is still highly optimized and suitable for legacy H2H communications such as voice calls, video streaming, online gaming and web surfing. M2M communications need a very different set of requirements than H2H communications because they are primarily characterized by a high equipment density in a cell, low traffic volumes per device and small amounts of payload. The main issue in front of LTE-Advanced is avoiding traffic load spikes caused by a sudden surge of huge numbers of M2M device attempting to access the LTE-Advanced's base station all at once. An example is the massive number of connected electric vehicles asking almost at the same time; particularly in peak time; for power charge from EVSEs. This leads to severe overload on the LTE-Advanced physical random access channel and performance degradation. The overloaded random access channel is further worsen if the connected-EVs try to repeat their access attempts thinking that the unsuccessful random access attempts are not due to random access channel overload.

Our contributions, in this paper, can be summarized as follows: (1) We propose an enhanced LTE-advanced access mechanism to counteract overload caused by sudden massive connected-EVs demands called, LTEEV; (2) we study the impact of such massive connected EVs demands on the smart grid networks; (3) we define two classes of service to give priority to power charge messages over comfort messages; (4) we integrate an admission control algorithm to LTEEV mechanism to avoid congestion in case of massive EVs demands especially for power charge messages; and (5) our admission control mechanism provides strict QoS to power charge messages in terms of short latency delay.

II. Related Work

M2M communications is a key to improve the power control in the smart grid especially in peak time. In this context, many studies focus on M2M communications but particularly for home energy management System in smart grid [6]. Since EV will become the vehicle of choice for the future, we need urgently to control the power charging to ask adequately the huge demands of the EVs in terms of latency time while balancing the charge on the EVSEs. For that, the wireless technology used to exchange such messages between EVs-EVSEs or EVs-OEM is a big challenge and needs to be described to answer such requirements. In the literature, new works proposed to use LTE-advanced technology since it is considered as central role in interconnecting machines [7-8]. However, LTE-Advanced faces some challenges such as signaling and traffic load spikes caused by a sudden surge of massive numbers of M2M devices attempting to access the LTE-Advanced's base station all at once. A generic architecture for M2M networks was proposed in [9] for hierarchical deployment which can allow reliable and efficient interaction between multiple communication protocols when there are limitations on cost, size and power. This architecture can be switable for electrical vehicular networking, in which different communication technologies are used as Zigbee at different stages to provide an optimum throughput and energy consumption.

Within 3GPP, the research identified six possible solutions [3] to avoid the physical random access channel overload problem as described below.

2.1. Backoff Scheme

The backoff scheme avoids the physical random access channel overload by separating between H2H and M2M terminals random access attempts. Under light and medium load conditions, the backoff scheme is proven to be effective. However, under massive number of machines initiating random access at once, unfortunately, it presented fewer performances. Therefore, this solution cannot be considered in massive EVs demands as we assume in our study.

2.2. Slotted-Access Scheme

Each M2M terminal, in the slotted-access scheme, is only allowed to transmit the preamble sequence at definite random access slots within specific radio frames (see Fig. 1). Otherwise, the M2M terminals are considered in sleep mode. Based on the M2M identity and the random access cycle (i.e., an integer multiple of radio frames), the M2M terminal computes random access slots and radio frames. Then, the base station broadcasts the random access cycle (see Fig. 1). It is worth noting that the number of unique random access slots is proportional to the random access cycle length and the number of random access slots within a radio frame.

If the number of M2M terminals in a cell is greater than the total number of unique random access slots, physical random access channel will be overloaded. In this case, several M2M terminals share the same random access slot and preamble collisions are unavoidable. A possible solution is to consider long random access cycle to reduce preamble collisions but it involves to unacceptably large latency in delivering random access requests.

2.3. Access Class Barring (ACB) Scheme

In Access Class Barring (ACB) scheme, the LTE-Advanced is enhanced to include new access classes for M2M terminals. Also, the base station can block or delay an M2M terminal from initiating random access. Therefore, by reducing the number of M2M attempting random access, the ACB scheme could face the excessive physical random access channel overload. But, this involves longer random access latency time for some M2M terminals.

2.4. Pull-based Scheme

In the pull-based scheme, the M2M server triggers LTE Advanced's base station to paging the intended M2M terminals. The M2M terminal will start random access upon receiving the paging signal. The number of M2M terminals to be paged is controlled by the base station by taking into consideration the physical random access channel load condition and available resources.

2.5.Physical random access channel Resource Separation Scheme

In this scheme, M2M and H2H terminals allocate orthogonal physical random access channel resources. We remark that when the M2M terminals share the same physical random access channel resources as H2H terminals, the random access quality of H2H terminals is degraded drastically as consequence to the channel overload. The source of overload is due to M2M or H2H random access activities which can be identified by the base station. Physical random access channel resources are random access slots and preamble sequences, which can be divided as follows: (a) M2M communications can be accomplished with random access slots that are orthogonal to those used for H2H; and (b) a subset of the preamble sequences from a common pool is assigned for M2M use.

2.6. Dynamic physical random access channel Resource Allocation Scheme

The base station dynamically allocates additional physical random access channel resources based on the physical random access channel load conditions and overall traffic load. To provide such allocation, the base station uses an algorithm that can respond at the onset of high load conditions (see details in [7]).

In the next section, we take into account these different solutions detailed above to propose a new one which takes advantages of them and avoids to have same problems particularly with the overload channel in case of massive access of the connected-EVs to the random access channel.

III. LTEEV SOLUTION

3.1 Current Physical random access channel (PRACH) description

The PRACH transmission (the PRACH preamble) is an OFDM-based signal, but it is generated using a different structure from other uplink transmission (see Fig. 1).

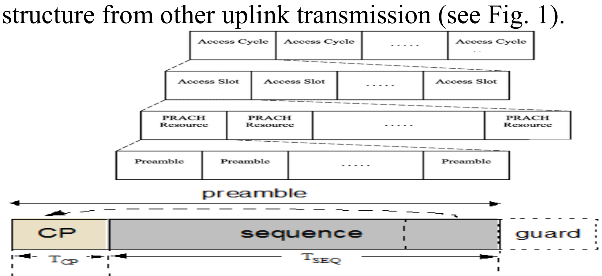

Fig.1. Physical random access channel (PRACH) : access cycle, access slot, preamble

Most notably it uses narrower subcarrier spacing and therefore is not orthogonal to the Physical Uplink shared Channel (PUSCH) and Physical Uplink control Channel (PUCCH). Therefore, those channels will suffer from some interference from the PRACH. However, the subcarrier spacing used by the PRACH is an integer submultiple of the spacing used for the other channels and therefore the PUSCH and PUCCH do not interfere on the PRACH. In our context, we are interested in communications between EVs-EVSEs and EVs-OEM via LTE-advanced technology.

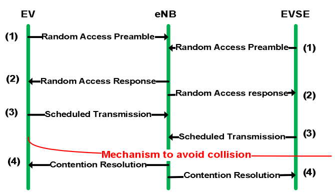

Fig.2. PRACH messages exchanges with an efficient mechanism to control collision in case of massive connections in the smart grid using LTEEV access method.

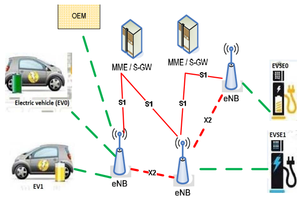

Fig.3. Connected EVs communications via LTE-advanced technology using PRACH access method

Fig. 2 shows for example the interaction that will be established between EV and EVSE using LTE-advanced based on the PRACH. After Step3, we face the problem of random access channel overload in case of massive connections from EVs. Specially, this could happen in peaks time. We conclude that an efficient mechanism should be engineered to combat collisions in high load conditions which means dense cell (i.e., huge number of users aim to charge their EVs at the same time). Such mechanism which we named LTEEV will be described in next sub-section 3.4.

3.2 Deployed architecture

In the upcoming next years where tens of thousands of connected-EVs will be connected to the grid performing one or multiple services, it is almost certain that the grid operator will not want to contract with each individual EV. Instead, the grid operator will want to have control over the power utilization of intermediary entities, called EVSEs that would manage the interactions between the grid operator and the connected EVs in a region. To the grid operator, the EVSE will be source of controllable power charging process and a good source of regulation electricity use. The grid operator and EVSE would communicate over a secure data link of the same type used to communicate with existing sources of regulation. The EVSE would receive power management commands from the grid operator and thus allocates the required power out to the connected EVs. A graphic of such system architecture is illustrated in Fig. 3. Because the charging times of vehicles batteries are long (tens of minutes for the fastest charging stations), it his highly advisable that a reservation process takes place prior to an EV heading to the EVSE. In this work, we consider that EVSEs and EVs use wireless communication such LTE-advanced to exchange such information, and we present a reliable two-way communication protocol between EVs-EVSEs and EVs-OEM to ensure the communication via the PRACH.

3.3 Impact on huge EV-2-EVSE attempts to the PRACH in the peak time

The current 3GPP/2 networks principally are engineered for H2H communications: voice call, SMS/MMS and server-to-human (streaming). However, these technologies might not be adequate for M2M application services, especially for massive communications.

In our context, EV-2-EVSE and EV-OEM smart grid networks are defined as communication without human intervention. Note that EV-2-EVSE/EV-OEM communications is characterized by a considerable number of machines equipments placed in a same cell. Accordingly, some or all of these connected-EVs may try to access the base station using random access shared channel simultaneously. As a consequence, random access preamble collisions are prominent and difficult to be avoided. Moreover, the authors showed in [10], that the performance of random access deteriorates when the number of machines performing random access attempts increases suddenly and it leads to a decrease of the number of available random preamble. Besides, such massive access increases significantly the latency time to serve machines as illustrated via simulations in [10].

In this paper, we aim to alleviate such challenges by controlling the random access resources by an admission control mechanism and adjusting the PRACH according to offered load conditions caused by massive attempts to the PRACH. In addition, we take into account a threshold latency time while serving connected-EVs to guarantee strict QoS in terms of delay.

3.4 Proposed solution: LTEEV Description

To date LTE-advanced random access method only uses a simple algorithm to adjust the PRACH transmission for each unsuccessful random access attempt. Moreover, the other network parameters/resources are not adapted dynamically according to the PRACH channel load condition change.

In the following, we describe our access method solution to avoid collisions in case of massive EV-EVSE/EV-OEM communications based on LTE-advanced technology to ask adequately the EVs demands in reasonable time (we called our method LTEEV). Firstly, the base station adjusts dynamically the PRACH resources according to the EVs priority demands; this means the base station takes decision to increase resources to special messages exchanges according to the load conditions on the PRACH.

Secondly, our LTEEV method differentiates service as done in the Access Class Barring (ACB) Scheme [3, 7] but in different way and for that, we consider different classes.

For service differentiation, and without loss of generality, LTEEV considers two classes of traffic: (a) Class of service 1 with quality of service requirements (e.g., delay); and (b) class of service 2 with no QoS requirements. We suppose that user requests (at EVs) come with their classes of service (class-1 or class-2) and their maximum latency delay (Δ_{delay}).

These two classes for EV-EVSE/EV-OEM messages are defined as follows:

-**Class of service1**: Messages to charge vehicles from EVSEs.
-**Class of service 2**: Messages to discover promotions, subscriptions, mechanical check, etc.

The messages containing information such power consumption, slots charging have higher priority to access the random channel using LTEEV method. We suppose that the other messages are not delay sensitive compared to power charging messages. This will allow avoiding overload channel caused by not urgent messages (i.e., promotions messages, etc.).

Third, LTEEV method is inspired from the slotted access method described in [3, 7]; to make advantage of this method particularly to transmit the preamble sequence at definite random access slots within specific radio frames. However, using this method as proposed, could lead to PRACH overloaded (a) if the number of M2M terminals (EVs and EVSEs) in a cell is greater than the total number of unique random access slots. Even (b) if we consider long random access cycle to reduce preamble collisions, it will involve to unacceptably large latency in delivering random access requests. So, LTEEV method tackles the first problem (a) by (a.1) giving priority to power charging messages (class 1); which reduces significantly the number of connections treated in one cell and also by (a.2) considering a new admission control method which evaluates the situation in a cell before accepting a new EV demand to a given EVSE. It is worth noting that the admission control module is implemented in each base station. The base station is responsible to check periodically (i.e., cycle) the state of each EVSE in its transmission range and the capacity of the PRACH. Moreover, LTEEV method solves the second issue raised by slotted access method introduced in [3] by adjusting random access cycle dynamically to avoid unacceptable large latency in delivering random access requests which is very desirable to guarantee QoS to EVs users in the smart grid.

It is worth noting that LTEEV method includes also detection module to highlight the case of PRACH overload since is not included in the current PRACH version. This detection is based on a parameter increased after a time t, the base station does not answer. In this case, we can say the random access trial is failed and then we initiate the overload module. In this case, the EV or EVSE will not randomly select and send the preamble sequence in the random access slot in the next random access cycle as mentioned in the standard [3] or they will not randomly draw a value q. So that, If q • p, the terminal proceeds to transmit the preamble sequence in the random access slot as proposed in [7]. The parameter p is the access probability which is set according to the access class of the terminal.

The two method proposed in the literature [3, 7], are able to reduce collisions but it is not enough in case of dense cell as we suppose in our paper.

In the following, we present an algorithm (see Alg. I) that describes our LTEEV method which is based on two known existing access methods called Access Class Barring (ACB) and slotted access [3, 7]. LTEEV proposes solutions to their drawbacks as explained above.

We assume that one radio frame is equal to 1 ms so the random access cycle; noted Cy; can be assigned to minimal value 1 ms but this value can lead to quick adjustment which is not desirable. Cy can be assigned to maximum value of 5 hundred of frame radio which can be 500ms. In this case, we face the problem of unacceptably large latency in delivering random access requests. That is why in LTEEV method, we adjust this value, $Cy \in [1..500]$ according to the network state estimated by the admission control module. Since, we give more priority to class 1, we assign the maximum resources utilizations on the PRACH in terms of random access slots to 70% and the class 2 to 30% in the initial cycle (Cy_0).

Algorithm I. LTEEV access method algorithm

Input: class 1=70%, class 2=30%, Δdelay;
Output: New resources for random access cycle (i+1);

```
1   Compute number of unique random access slots based on the
    Cy length and the number of random access slots within a
    radio frame, noted NU.
2   While (Cy_i start)
3     Receive request demands from EVs in a cell
4     Evaluate number of EV-2-EVSEs communications: N
5     If (request belongs to class 1) && (N ≥ NU) Then
6       If ( Detection (Overload_Indicator )) Then
7         If (no messages belonging to class 2)
8           Adjust max resources assigned to class 1 to 90%
9         EndIf
10      EndIf
11    EndIf
12    If (class 1 is 90%) && (N ≥ NU)
13      Call admission control procedure   EndIf
14  Until (Cy_i==0)
15  Compute new resources for random Cy_(i+1): Eq.7
16  Broadcast new resources assigned to the PRACH for Cy_(
    i+1)
```

To compute the new resources (i.e., random access slots; R') for the PRACH for the Cy_(i+1) in Alg. I line 16, we take into account fail random access attempts from M2M communications (noted ATT) and total attempts to the PRACH happened in the previous Cy_(i) (noted ATTotal). We assume:

- Φ is the random access collision probability in a cell by N EVs,
- ATTotal is the number of random access attempts per second per cell,
- $ATTotal_{EV}$ is the expected number of chosen sub-frames by one EV,
- R is the total number of random access resources per second and is computed by the base station for every Cy,
- RAS is the number of random access slots per second,
- RAF is the number of random access frequency bands,
- NPS is the number of preamble sequences in the cell for M2M communications with a maximum of 64.

$$R = RAS * RAF * NPS \qquad (1)$$

The random access success probability; RASP; is defined as the probability that EV's preamble sequence does not collide with another preamble sequence in contention phase.

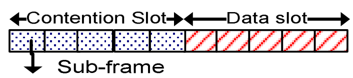

Fig.4. Reservation access slot in PRACH

We express the fraction of EVs that succeed on the contention phase as follows:

$$\text{RASP}= \frac{ATTotal_{EV}}{ATTotal_{EV} + \phi} \qquad (2)$$

Pr: the probability that in a given contention slot there are a *k* EVs contending. We assume that the numbers of EVs contenting per slot are modeled by the random variable X.

$$\Pr[X=k]=\binom{N}{k}\left(\frac{1}{NPS}\right)^{k}\left(1-\frac{1}{NPS}\right)^{N-k} \quad (3)$$

We assume that there is k contending EVs, each EV randomly chooses a preamble and a sub-frame (see Fig. 4) of the virtual frame in which the preamble is sent.

The expected number of chosen sub-frames by one EV is expressed as follows:

$$ATTotal_{EV}=\Pr[X=1]*NPS \quad (4)$$

Where the number of preamble sequences in the cell is expressed as follows:

$$NPS=L*N \quad (5)$$

The random access collision probability in a cell by *k* EVs is expressed as follows:

$$\phi = \Pr[X \succ 1]*NPS \quad (6)$$
$$= [1-\Pr[X=0]-\Pr[X=1]*NPS]$$

Therefore, random access slots for Cy_(i+1) can be expressed as follows:

$$R'_{(Cy+1)}=R+\left|R\times\left(\frac{ATT}{ATTotal}\times(1-RASP)\right)\times\phi\right| \quad (7)$$

The best case when the succeed contention fraction equals to 1 and the collision probability equals to 0. Then, the number of random slots in Cy+1 is equal to R. The worst case the collision probability equals to 1 and RASP is equal to 0. Then the resources will be increased two times. Otherwise, the resources depends on the fraction of collision and successful transmission on the PRACH as computed in Eq (7).

Then, we describe the two modules called detection and admission control, resp.

Module. Detection (Overload_Indicator) procedure

Input: class 1, ATT=0, MAX_{ATT}, ATTotal=0; Output: Boolean;

1 Increment random access attempts: ATT++;
// received from EV or EVSE if they fail to access the PRACH, i.e., the base does not answer after TTL time.
2 ATTotal=ATT+Transmission_Preamble_Counter;
// computed based on MAC preamble transmission attempt counter parameter (Transmission_Preamble_Counter).
3 **If** (ATTtotal ≥ MAX_{ATT}) &&(messages belong to class 1)
4 **Then** return **overload_Indicator** =true
5 **Else** return **overload_Indicator** =false **EndIf**

Module. Admission control procedure

Input: class 1, class 2, ***CI**$_{EVSE}$*: initial capacity on EVSE;
Output: reject/accept demands to access smart grid network;

1 Measure current percentage capacity on each EVSE in same range : C_{EVSE}
2 **If** ($C_{EVSE} =_{\alpha}$ x ***CI**$_{EVSE}$*) **&&** (demand from EVi belongs to class 2) && **(**demand from EVj belongs to class 1)
3 **Then** Reject demand from class 2
If (computed latency time on EVi $\le \Delta_{delay}$)
Then Accept demand from class 1 **EndIf**
4 **While** (no demand from class2) && (latency time EVi > Δ_{delay})
5 Reject demand from class 1
6 Adjust Cy in [1..500]
7 **Until** latency time $\le \Delta_{delay}$ //resources utilization decreases
8 **EndIf**

IV. Simulations Results

In this section, we conduct an analytic study using Matlab to evaluate and compare the performance of our proposed scheme, i.e., LTEEV, with traditional PRACH scheme. We evaluate several performance metrics: 1) the latency time; 2) the resources utilization; 3) the power consumption; and 4) the number of blocked requests.

5.1 Simulation Configurations

The parameters are presented in Table 1. It is worth noting that, in the analytic results, we are using PRACH with admission control for LTEEV and without admission control and without resources management for traditional PRACH, i.e., we note TPRACH in the related work to which we compare.

Table I. Simulations parameters

Δ_{delay}: latency time constraint	190 ms	Number of OEMs	1
Cy: an integer multiple of radio frames (cycle)	[1..500]	Number of slots in Cy	5
Number of cycle	15	Access slot (ms)	5
α: remaining power capacity on EVSE	10%	Access PRACH (ms)	2.5
Number of EVs of class1	400	Preamble (ms)	0.5
Number of EVs of class 2	200	Number of EVSEs	1

5.2 Discussion : All graphs based on cycle variation

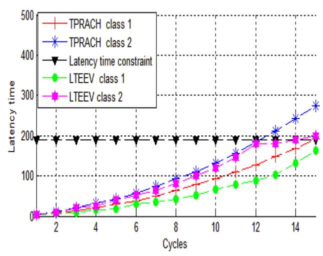

Fig.5. Latency time (ms) variation with LTEEV versus TPRACH

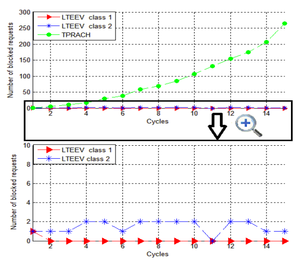

Fig.6. Blocking variation with LTEEV versus TPRACH

In Fig.5, we study the performance of our proposed LTEEV based on latency time constraint for two classes of services. For the related work, since regular PRACH, namely, TPRACH, does not provide a flexible constraint on access latency time beyond the used cycle, we consider only the cycle length as constraint to accept an EV request.

We notice that the average latency experienced by the PRACH enforced by our proposed admission control LTEEV is bounded by a much lower latency time (in average is 57 ms for class1 and 80 ms for class 2 using LTEEV), i.e., at least an improvement of 19% for class 1 and 20 % for class 2, compared with that of the TPRACH (76 ms for class1 and 109 ms for class 2 using TPRACH). This is explained by the lower access delay of PRACH when we limit the number of contending vehicles with our LTEEV compared with that of

TPRACH; the latter generally waits to transmit vehicles belonging to class 1 or 2 time slots, even though it is bounded with a cycle utilization threshold. It does not consider priority between comfort messages and charge requests messages.

We remark that vehicles using service class 1 are served in very acceptable delay that does not exceed the 170 ms while using TPRACH, the vehicles from class 1 exceed the predefined threshold, 190 ms, e.g., cycle=14.

From Fig. 5, we notice that the delay threshold is reached starting from cycle 12 since the number of requests blocked in Fig. 6 experienced by TPRACH becomes significantly greater than that experienced by LTEEV.

In fact, to guarantee a latency time not exceeding the given threshold, our proposed Blocking LTEEV has to block only a little more request for class 2 compared with TPRACH.

In Fig. 6, the admission control module rejects requests from class 2 which is expected from our scheme since we prioritize charge messages (class 1) over comfort messages (class 2). We notice even LTEEV rejects requests; the blocking rate is very acceptable over all the cycles. We conclude that our scheme provides good QoS in terms of vehicles latency time and blocking rate of both classes of services.

Fig.7. shows the power consumption of EVSE, we can notice that all cycles are well managed and adjusted as described in Alg. I to serve EVs users. This is highlighted by Fig. 8 where the resources reserved to class 1 and class 2 are adjusted expect on cycle 11. It is worth noting that in the cycle 11, no admission control is occurred because all class 1 and class 2 are served as shown in Fig.8. The number of blocking request is equal to 0 for both service classes using LTEEV in cycle 11.

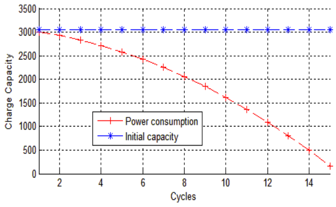

Fig.7. The power consumption variation for LTEEV

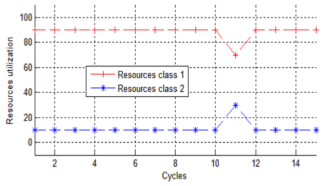

Fig.8. The resources utilization for LTEEV

Fig.9 and Fig. 10 show the satisfied vehicles demands from class 1 and class 2 resp. in each cycle to highlight how our proposed algorithm, Alg. I, is able to adjust adequately the resources in each cycle to face the overload problem and then to avoid collated vehicles slots in the same cell as faced in the related work [3]. One can argue that we do not need explicit admission control in Smart grid because the PRACH as it presented in the literature is bounded delay because of the cycle notion. Two issues are raised here: (a) adjusting the resources for each cycle is a challenge, we must find the more accurate size of the cycle between [1..500] which is not easy at all and (b) with high value of the cycle we can serve more vehicles but in the same time, it will involve high latency time. While short value will implicate overload network and slots collision between vehicles attempting to access the PRACH in the same time. But, shot cycle may provide short latency time for not collided vehicles in the cell.

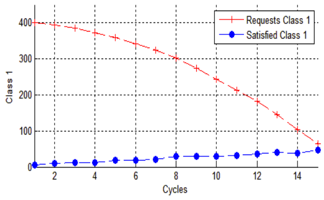

Fig.9. The requests of EVs (class 1) versus satisfied EVs in the smart grid for LTEEV

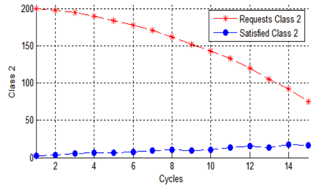

Fig.10. The requests of EVs (class 1) versus satisfied EVs in the smart grid for LTEEV

V. CONCLUSIONS AND FUTURE WORK

In this paper, we have proposed a new PRACH access based on an efficient admission control algorithm using LTE technology, called LTEEV, to support two services classes in the smart grid. Particularly, we have considered latency time as a major criterion in the design. Simulations show that LTEEV can efficiently prevent the latency time of each electric vehicle belonging to class 1 or class 2 in the smart grid from exceeding predefined threshold. Furthermore, we have concluded from our performance study that the regular PRACH enforced with our latency time constraint admission control and resources adjustment as shown in Alg. I is able to avoid both long latency of EVs users and networks overload in high offered load conditions in peak time.

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