A Congestion Control Approach for M2M Networks

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***Abstract*—Machine-to-Machine (M2M) is a communication model used by devices where data can be exchanged with little or no human intervention. The M2M communication, when applied in the context of LTE networks, can lead to overload and congestion problems due to its intrinsic particularities. Accordingly, in this paper we propose a congestion control approach for Long-Term Evolution (LTE) that reduces the impact over the Human-to-Human (H2H) devices and establishes priority amongst M2M devices through the use of classes. The results obtained through extensive simulations in Network Simulator (NS-3) show that the proposed approach can control the impact over H2H devices, establishes intra and inter-class priority for the devices, reduces the access delay and it is compatible with the LTE network standard.**

Keywords–LTE; M2M; Congestion Control

I. INTRODUCTION

M2M communication is a technology that enables information exchange between autonomous devices with few or no human intervention [1]. Device types can be of common (e.g., home appliance, cars, cell phones, etc.) or specific purpose (e.g., sensors, actuators, etc.). The M2M communication is expected to play an important role to leverage the Internet of Things (IoT). The goal of the IoT paradigm is to facilitate daily tasks, generating a huge impact on society behavior [2].

The Long-Term Evolution (LTE) [3] is a networking standard that presents advantages like mobility, accessibility, good coverage area, security, and other relevant key features for M2M services and applications. Since LTE networking was mainly designed for H2H communication, some adaptations need to be done to cope with M2M communication requirements. The Third Generation Partnership Project (3GPP) [4], organization that is responsible for the LTE specification, works to identify and propose solutions for the problems and requirements that may arise with the integration of M2M devices into the LTE network.

The overload and congestion control in the LTE Radio Access Network (RAN) is considered by 3GPP as a high priority issue that needs to be treated to enable the M2M communication over the LTE networks. Overload and congestion on LTE network normally occur when a huge number of access requests are sent by devices to a single base station during the Random Access CHannel Procedure (RACH procedure). The RACH procedure presents a very low efficiency as the number of devices increases [5]. In Section II, we present an overview of the LTE networks and the RACH procedure.

The 3GPP presents six alternatives to mitigate the overload and congestion problems on the LTE network: (i) Access Class Barring (ACB), (ii) Backoff, (iii) Separated RACH, (iv) Dynamic Resource Allocation for RACH, (v) Slotted-Aloha and (vi) Pull Schema. Some approaches in the literature (e.g., [6], [7], [8]) combine two or more of these mechanisms to achieve better results. However, the solutions to mitigate the overload and congestion problems normally consider only the M2M traffic in their approaches [5]. Another drawback in these proposals is the lack of compatibility with the LTE standard. The related works are presented and discussed in Section III. These problems have motivated the development of our proposal. In this paper, we propose a mechanism, presented and discussed in Section IV, to mitigate the congestion in the RAN of LTE networks that presents low implementation complexity. In addition, in our solution, we propose mechanisms to control the impact of M2M over H2H devices and we create priorities among M2M devices. To accomplish these objectives, we split the M2M devices into high and low priority classes and we define a third class for H2H devices.

The results obtained through exhaustive simulations using NS-3, presented and discussed in Section V, show that our approach presents good results for inter and intra-class priority for M2M and H2H devices. Moreover, our approach is highly compatible with the LTE networks, easily implemented and mitigates the congestion problems during the RACH Procedure. In Section VI, we present our conclusion and future works.

II. OVERVIEW

A. *Machine-to-Machine Communication*

The M2M communication, also called Machine-Type Communication (MTC) by 3GPP, is a technology where devices can exchange information with little or no human intervention. In addition to the applications diversity and number of devices, other common features of M2M communication are [9]: (i) traffic in the uplink is higher than in the downlink, (ii) sporadic data transmission, (iii) usual transmission of small portion of data. Thus, due to these intrinsic features new approaches are needed to adapt the LTE network to the M2M environment.

B. *RACH Procedure*

In LTE networks, the random access can be contention-based or contention-free. In the former, the random access request is initialized by the device. In the latter, requests are started by the base station (evolved Node B - eNodeB).

The contention-based RACH procedure is divided into four signal messages (represented in Figure 1, mgs1, msg2, msg3, msg4) managed by the Radio Network Controller (RNC) [10]. Figure 1 illustrates the message exchange during the contention-based procedure. Information related to the

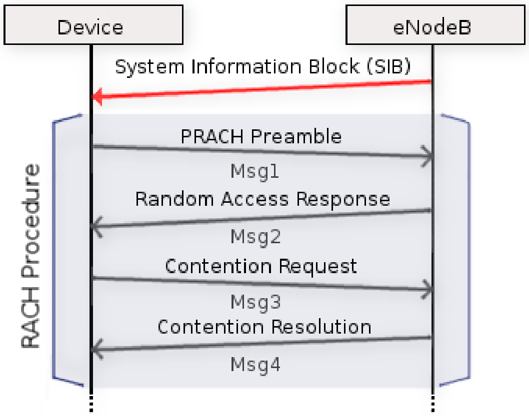

Figure 1. Random access procedure based on contention.

RACH procedure, as preamble code available and random-access slots (RA-Slots) opportunities, is periodically sent through the System Information Block (SIB) to devices. The following activities are done in each stage of the RACH message exchange procedure:

1) PRACH Preamble (Msg1): The device randomly selects and transmits a preamble code to eNodeB on Physical Random Access CHannel (PRACH).
2) Random Access Response - RAR (Msg2): In this stage, the following occur: (i) detection of access requests sent by devices to eNodeB, (ii) assignment of a Temporary Cell Radio Network Temporary Identifier (TC-RNTI) to devices and (iii) a resource is granted on the uplink channel for subsequent messages exchanges between the devices and the base station.
3) Contention Request (Msg3): Devices send the TC-RNTI, the one assigned in the previous message. This exchange is done over the uplink shared channel (PUSCH), also configured in previous stage.
4) Contention Resolution (Msg4): Devices wait for the contention resolution message from the eNodeB, which is sent by the eNodeB through the Downlink Shared Channel (DL-SCH). If the device identifier is present in the contention message, an ACK message is sent to the eNodeB, otherwise the device randomly select a backoff time before retry transmission.

Collisions during the RACH procedure occur when two or more devices send the same preamble code to the eNB. In this case, devices do not receive the Random Access Response (msg2) and the waiting time window is reached.

III. RELATED WORK

In [11], devices are classified into classes. Class priorities are based on the backoff time. When a collision occurs, the device waits for the backoff time, which is randomly selected from the interval ($X \sim Unif(0,T)$), where X is a random variable and $Unif$ an uniform distribution. The interval (T) is divided by the number of classes (C) with the interval size based on the congestion level (p_0) broadcasted by the base station. The interval range for M2M devices is given by the following equation: $T_{bf}^{MTC}(i) = p_0T + Unif(i\frac{(1-p_0)T}{C}, (i+1)\frac{(1-p_0)T}{C})$. To prevent that the M2M interval becomes equal to zero when the networks is congested, the authors propose the following equation for the backoff calculus: $T_{bf}^{MTC}(i) = T + Unif(i\frac{kT}{C}, (i+1)\frac{kT}{C})$. Another strategy presented by the authors is to change the backoff range based on the M2M device class. Using this second approach the backoff calculus is done by the following equation: $T_{bf}^{MTC}(i) = Unif(0, k_iT)$, where k_i represents the multiplier of the ith type of MTC user. The second strategy can be seen as an enhancement of the specific backoff schema with the adoption of more than one type of M2M devices. The third approach combines the ACB with the backoff class. Since our main priority is to analyze the performance of backoff strategies with our approach, we choose to implement the first approach. Classifying devices into classes with different backoff interval represents an upgrade when compared with the conventional backoff and the Slotted Aloha approaches. However, this approach is not optimized. The interval class does not consider the number of devices in each class. Thus, classes with a few hundreds of devices have the same interval size as classes with thousands of devices. Moreover, there are no intra-class priorities among the types of M2M devices.

In [7], the authors propose a static and a dynamic approach to split the RACH resources between M2M and H2H devices. Before the resource allocation, the devices pass through the ACB selection. The implementation complexity and no prioritization between devices are some of the drawbacks of this approach. In [12], an algorithm is proposed that helps devices to select the base station (eNodeB) which they should be connected to. The algorithm uses a Q-Learning technique and considers the application Quality of Service (QoS) during the selection. In this proposal, no priority is defined among M2M devices and it is applied only to scenarios where the devices are covered by more than one eNodeB.

In [13], the idea is an overload control mechanism that uses the dynamic resource allocation for RACH technique. To identify the overload level at the RAN in the LTE networks, the authors consider the average number of preambles sent by devices to get access to the network. The algorithm considers the number of retries made by the devices before successfully accessing the network to infer the congestion level into the network. The authors also combine other 3GPP proposal techniques (Slotted-Access, Backoff and ACB) to mitigate the M2M impact over the H2H devices and define priority between M2M devices. This approach has a high complexity level of implementation and was not evaluated by simulation or by analytical approach.

In [14], the authors present a testbed framework to analyze the congestion control strategies of LTE networks. The congestion caused by M2M devices can impact other domains of the network (e.g., core network). However, better results are achieved by the strategies applied in the RAN [12].

IV. CONTROL CONGESTION PROPOSAL

In this section, we present our proposal to control the congestion in LTE networks. Our goal is: (i) to reduce the impact on H2H devices, (ii) to define inter and intra-class priorities among the devices and (iii) to increase the success access rate. The inter-class behavior presented in our approach is defined between the H2H, M2M with high priority and M2M with low priority. The intra-class priority is among the same type of M2M devices, with higher priority given for those devices that are more likely to reach the maximum number of connection tries. Furthermore, in Section IV-A, we describe the congestion problem during the RACH procedure in LTE networks.

A. Problem

The RACH procedure in LTE networks follows the Slotted Aloha principle [15]. Based on this relation, it is possible to use the following equation to estimate the collision probability (P_c) during the RACH procedure [16], [17]: $P_c = 1 - e^{(-\lambda/L)}$, where L is the total number of Random Access Slots (RA-Slots) available per second and λ is the average number of requests per second targeting a single eNodeB. For a bandwidth (B) in MHz, such that $B \in \{1.4, 2.5, 5, 10, 15, 20\}$ the number of Physical Resource Blocks (PRBs) available per frame is given by: $PRB_{TotalFrame} = {}^{B}/_{F_{subframe}} \times T_{frame} \times 2$, where T_{frame} is the frame timing in milliseconds and $F_{subframe}$ is the frame frequency in kHz. Since an RA-Slots can be configured to occurs n times within a T_{frame} interval, where $n \in \{0.5, 1, 2, 3, 5, 10\}$, the number of PRB available per second for the RACH procedure is given by: $PRB_{Total} = {}^{PRB_{TotalFrame}}/_{2} \times {}^{1000}/_{T_{frame}} \times n$. Thus, the base station can support T_{RAR} request per second, where T_{RAR} is given by the following equation: $T_{RAR} = {}^{PRB_{Total}}/_{PRB_{RACH}}$ Where PRB_{RACH} is the number of Physical Resource Blocks per RACH request. In LTE networks, the number of PRB_{RACH} is equal to six. For a given collision probability (P_c), the number of RA-slots per second (L) to support the random access intensity (λ) is given by [17]: $\lambda = -L \times ln(1 - P_c)$. Thus, more collisions will occur as the number of devices increases.

B. Proposal

Mechanisms to control the overload and congestion problems presented in Section I and III may be considered as good approaches to mitigate the problem. However, except for [11], these mechanisms present a high implementation complexity, with changes on the physical layer of LTE network. In [11], the implementation is based on how devices calculate the backoff interval and how the base station infers the congestion level in the RAN. However, this approach does not consider the number of devices during the class division. Accordingly, the algorithm defines the network resources for classes with the same interval range regardless of the number of devices in each class. In addition, this approach does not consider priority among M2M devices.

1) Congestion Level Identification: In our approach, the base station classifies and reports as low, medium, and high the congestion level in the RAN of LTE network. This classification is based on the results obtained in [18] that show the relation between the average number of access attempts, the collision probability and the RACH procedure ratio utilization. These results show that for a maximum resource utilization, which is approximately 50%, the collision ratio is around 20% and the proportion of successful requests is about 50%. Thus, when more than 50 requests are done per RA-Slot we consider the congestion level as high ($P_{cong} = 1$). However, we consider the congestion level as low ($P_{cong} = 0$) when there are less than 25 request per RA-Slot. The relation between the number of requests and the congestion level adopted in our approach is presented in Table I.

TABLE I. CONGESTION LEVEL

Level	**Request per RA-Slot**	P_{cong}
Low	< 25	P_{cong} = 0.0
Medium	> 25 and ≤ 50	P_{cong} = 0.5
High	> 50	P_{cong} = 1.0

2) Devices Priority: We classify the devices into H2H, M2M with high priority and M2M with low priority [6]. To guaranty priority in accordance with the device type, we use a class-based approach. The priorities between classes are based on the preamble transmission probability and backoff interval. The preamble transmission probability indicates when the device can send an access request. Based on the ACB approach, to get access to the network the device has to calculate a random number $X \sim Unif(0, P_s)$ within the interval (0,P_s), where P_s is giving by:

$$P_s(i,t,L) = \begin{cases} p_{ac} & P_{cong} = 0.0; \\ p_{ac} \times (((\frac{L}{t}) \times i) \times \alpha) & P_{cong} = 0.5; \\ p_{ac} \times (((\frac{L}{t}) \times i) \times \alpha) & P_{cong} = 1.0; \end{cases} . \tag{1}$$

where i is the device type (H2H, M2M low priority, M2M high priority), p_{ac} is the blocking parameter broadcasted by the base station (eNodeB), L is the maximum number of preamble retransmissions and t is the number of requests sent to access the network. The α parameter is related to the congestion level on RAN and defines the dispersion between the classes of devices. The results show that an optimized value for α is 1.0 when P_{cong} = 0.5 and 1.5 when P_{cong} = 1.0. The calculus of the expected transmission probability of a device k from a class i is given by:

$$E[X] = \frac{1}{2} \times (0 + P_s(i_k, t_k, L)) \tag{2}$$

Following the ACB behavior, the device can transmit an access preamble request during the RACH procedure when $X \leq p_{ac}$, i.e., with the probability given by $P_{access}(X \leq p_{ac})$. To conclude, the cumulative density function (CDF) F_X of a device k from a class i after t access attempts is given by:

$$F_X(x) = P(X \leq p_{ac}) = \frac{p_{ac}}{P_s} \tag{3}$$

Based on (2) and (3) the preamble transmission probability increases with the class index and the number of access attempts made by the device, as illustrated in Figures 2 and 3. These figures also show that as the number of classes increases the preamble transmission probability for classes with low priority decreases. However, for the number of classes considered in our algorithm, the probability of a preamble transmission can be around 50% for the class with low priority. When X is greater than p_{ac} ($X > p_{ac}$) the backoff $T_{backoff}$ is individually calculated by each device through the equation:

$$T_{backoff}(i) = \begin{cases} 20\ ms & \text{for i = 0;} \\ 50\ ms \times i & \text{for i} \geq 1; \end{cases} \tag{4}$$

The backoff technique avoids successive requests from devices to the base station (eNodeB) after a collision.

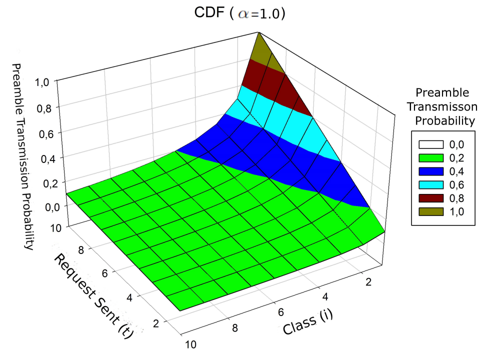

Figure 2. Cumulative Density Functions (cf. Eq. 3)

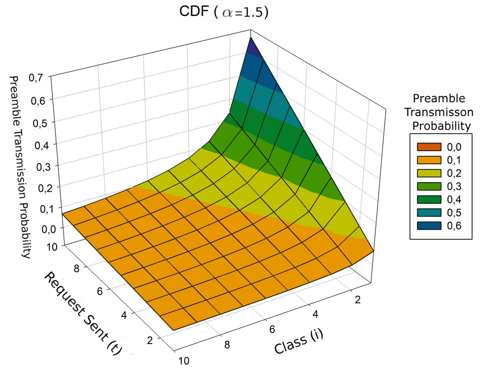

Figure 3. Cumulative Density Functions (cf. Eq. 3)

V. SIMULATION ENVIRONMENT AND NUMERICAL RESULTS

In this section, we present and analyze our simulation results. In Section V-A, we present the Performance Key Indicators (PKIs) selected to evaluate the implemented approach. In Section V-B, we describe the simulation environment and the configuration parameters.

A. *Key Performance Indicators*

In this paper, the performance indicators to analyze the approaches are the access delay, the blocking probability, the number of accesses, and the number of transmitted preambles. We define the access delay as the time interval between the instant when the device sends the first access request to the base station, and the time when the device successfully receives the contention resolution message from the base station. The blocking probability is the ratio between non-successful accesses and the total number of access requests received by the base station. The number of transmitted preambles indicates the access retries sent by the device to access the network. Such indicators will be useful during the analysis of the following aspect of each strategy: (i) impact control of M2M devices over H2H devices, (ii) priority between M2M devices and (iii) energy efficiency during the RACH procedure.

B. *Simulation Environment*

To evaluate our approach, we choose the simulator NS-3 [19]. The official version of NS-3 has a LTE module, but some key features of the RACH procedure were not implemented at the time this paper was written. Moreover, for the number of M2M devices simulated in this paper the simulator performance can become extremely low. Thus, we have extended the LTE module to implement other functionalities for the RACH on NS-3 for this paper.

TABLE II. PARAMETERS OF THE SIMULATIONS

General Parameters	
Bandwidth	5 MHz (25 RBs)
Runs	15
Number of base stations(eNodeB)	1
PRACH Configuration Index	6
Preamble Retransmissions (L)	10
Preamble Codes	54
Random Access Response Timeout Window	5 ms
H2H Devices	{ 100,100,100,...,100 }
M2M Devices With High Priority	{ 10,500,1000,...,4000}
M2M Devices With Low Priority	{ 2,125,250,...,1000 }
Arrival Rate (H2H)	Poisson(λ), λ = 1/300
Arrival Rate (M2M)	Poisson(λ), λ = 1/900
Arrival Interval	[0,...,1] s
Simulation Time	5 s
Other Parameters	
i = 0 for H2H devices, i = 1 for M2M devices w/ high priority, i = 2 for M2M devices w/ low priority.	
α = 1 for Low Congestion Level, α = 1.5 for High Congestion Level (cf. Table I).	

We have also implemented three algorithms found in the literature that are compatibles with the LTE network. The first ones is the Slotted Aloha, which is the most naive solution implemented and which gives a good understanding of the congestion problem during RACH procedure. The Backoff Specific, which defines different backoff interval for M2M and H2H devices, is the second implemented approach [20]. The third approach is presented in [11] and differs from the Slotted Aloha and Backoff Specific by setting priority among M2M devices. In [11], the devices are classified into classes with different levels of priority. The priority among classes considers the backoff interval such that access requests can be more or less spread over the time.

In our scenarios, we simulate H2H and M2M devices, where the number of H2H devices is constant and equal to 100. The M2M devices priorities are classified into high and low as presented in Section IV-B2. The number of M2M devices with low priority are: {10, 500, 1000, 1500, ... ,4000}, and the number of M2M devices with high priority are: {2, 125, 250, ... , 1000}, i.e., $\frac{1}{4}$ of the number of M2M devices with low priority. The arrival rate considered for the H2H and M2M devices follows the Poisson distribution with arrival parameters $\lambda_{H2H} = \frac{1}{300}$ and $\lambda_{M2M} = \frac{1}{900}$. The number of preamble codes available for RACH procedures is 64 - N, where N is the number of codes dedicated for the contention-free random access method and equal to 10. For the PRACH Configuration Index 6, we have two RA-Slots available per LTE frame (10 ms), and so we have 200 RACH/s (1000 ms / 10 ms × 2). For a bandwidth of 5 MHz, there are 25 PRBs available for each 0,5 ms, and knowing that each RA-Slots occupies six PRBs in the frequency domain and one subframe on the time domain, the base station (eNodeB) can handle four requests per PRACH procedure. Thereby, in an ideal scenario, i.e., without collision, 800 (200 RA-slots/s × 4) devices can get access to the network within the interval of one second. The above configurations are presented in Table II.

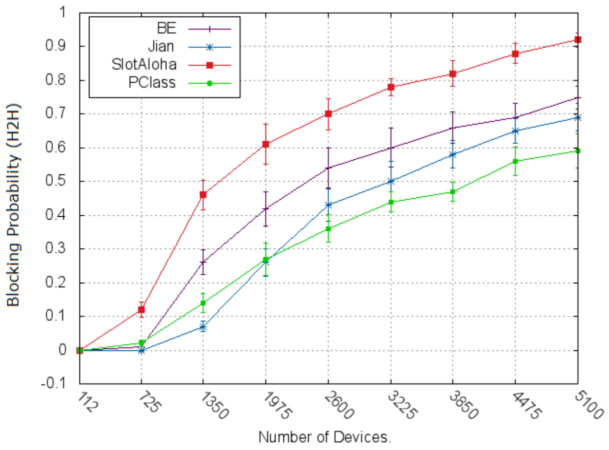

Figure 4. Impact Control Over H2H Devices - Blocking Probability.

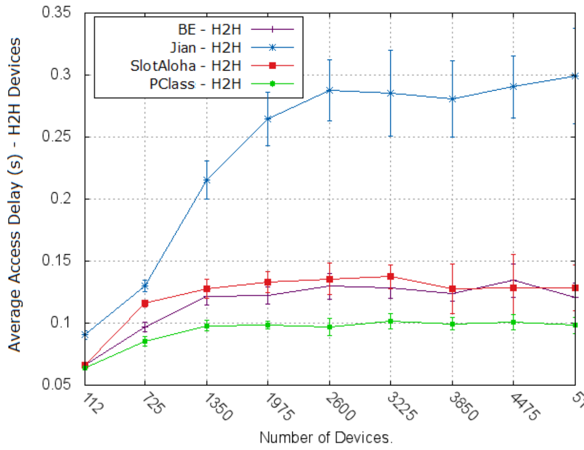

Figure 5. Impact Control Over H2H Devices - Average Access Delay.

C. Simulated Congestion Control Mechanisms

The approaches [11], [17] have in common with our approach the implementation viability in a practical context of the LTE networks. In [11], three techniques to split the classes are presented. However, for the reasons already presented (cf. Section III), only the first technique is implemented in this paper. Since there is no information in [11] on how the authors identify the congestion level in the RAN, we choose to apply the approach presented in Section IV-B1. The default backoff time configured to the network is set to 20 ms [17]. In [17] an Specific backoff approach is presented, in this approach H2H and M2M devices receives different backoff interval value. The maximum backoff value for M2M devices of 920 ms is within the defined arrival interval presented in [17]. To keep this behavior for scenario used in this paper, we define the maximum backoff time for M2M devices limited to 100 ms (Arrival Interval / Number of possible retransmission attempts).

D. Results

In the next sections, the approaches presented in [11], [17] will be respectively referenced by ”Jian” and ”BE”. The scenario where no congestion control is applied will be referenced as ”SlotAloha”. As presented in Section V-A, the performance indicator will be useful to analyze the following features: (i) impact control of M2M devices over H2H devices, (ii) priority between M2M devices and (iii) energy efficiency during the RACH procedure. Besides, our approach is referred by PClass.

1) Impact over H2H Devices: The relation between the blocking probability and the number of devices illustrated in Figure 4 shows that PClass has a performance improvement of 19% when compared to Jian and 40% when compared to SlotAloha. For around 1350 devices, the performance of Jian is about 10% better than PClass. However, between 1900 and 2000 devices, occurs an inversion on the blocking probability, i.e., PClass approach is able to handle congested scenarios better than Jian algorithm.

The priority inversion around 1975 devices is related to the congestion level (P_{cong}), explained in Section IV-B1. Scenarios with moderate level of congestion (P_{cong}) are less restrictive. In this case, more M2M devices try to access the network. Thus, more collisions may occur and emphasize the impact over H2H devices.

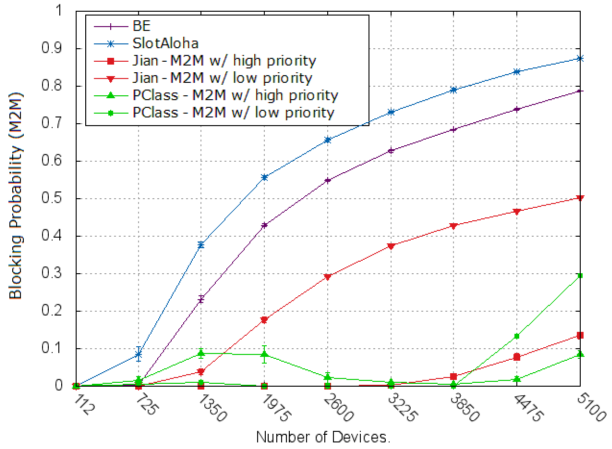

Figure 6. Impact Control Over M2M Devices - Blocking Probability.

As illustrated in Figure 5, the access delay is almost constant for all implemented techniques. However, it is important to notice that the average access time considers only devices that accessed the network with success. Thereby, even if the average access time of the H2H devices is considered constant, it can be observed in Figure 4 that the number of successful accesses decreases. The algorithm Jian considers a big backoff interval for the H2H devices. Accordingly, the access delay of H2H devices increases, since the access requests are more spread over the time.

2) Priority Between M2M Devices: As illustrated in Figure 6, the blocking probability increases with the number of devices in all implemented approach. Once the algorithms SlotAloha and BE do not define priority between devices, both types of devices (H2H and M2M) are equally penalized.

In the SlotAloha and BE algorithms the requests sent by M2M devices are spread into the interval of 20 ms and 100 ms, respectively. As the interval increases, the number of collisions decreases and more devices has access to the

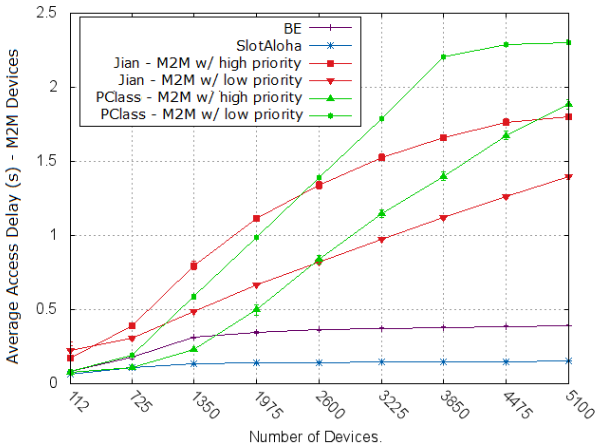

Figure 7. Impact Control Over M2M Devices - Average Access Delay.

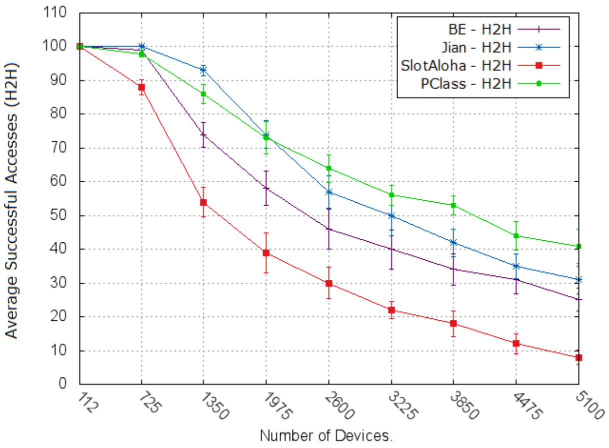

Figure 8. Average Succesful Access - H2H Devices.

network with success. The results presented by Jian are better than SlotAloha and BE since they define priority between M2M devices. In relation to PClass, the Jian algorithm presents a performance around 12% better for the blocking probability between M2M devices with high priority for scenarios with around 725 to 3530 devices. However, the PClass presents a better performance in scenarios with more than 3530 devices. In relation to M2M devices with low priority, the technique applied by the algorithm Jian behaves like SlotAloha and BE, i.e., the access time increases with the number of devices. The PClass algorithm presents the same performance as Jain, when compared with SlotAloha and BE in relation to the priority between M2M devices. Notice that PClass exceed the number of retries within scenarios less congested, i.e., those with fewer devices (around 1350), see Figure 6. However, for more congested scenarios, the algorithm PClass shows better results amongst the implemented approaches. The behavior presented by the PClass algorithm for scenarios within the interval of 1350 and 3850 devices is consequence of the parameter P_{cong}, which affects the devices transmission probability (cf., Equations 1 and 3).

3) Successful Access: As illustrated in Figures 8 and 9, the impact over the H2H devices increases with the number of M2M devices. The algorithms Jian and PClass have a similar behavior, however, the PClass algorithm converges to higher values than Jian. For scenarios where the number of device is above 1800, the PClass offers better access performance than Jian (cf. Figure 5).

For the M2M devices with high priority, the PClass algorithm presents advantage in relation to the number and average access delay for scenarios with about 1350 devices when compared with Jian (cf., Figure 9 and 7). However, for scenarios with more than 1350 devices, the average access delay of the PClass algorithm is higher than Jian algorithm, but PClass presents a better access performance of H2H devices than Jian algorithm.

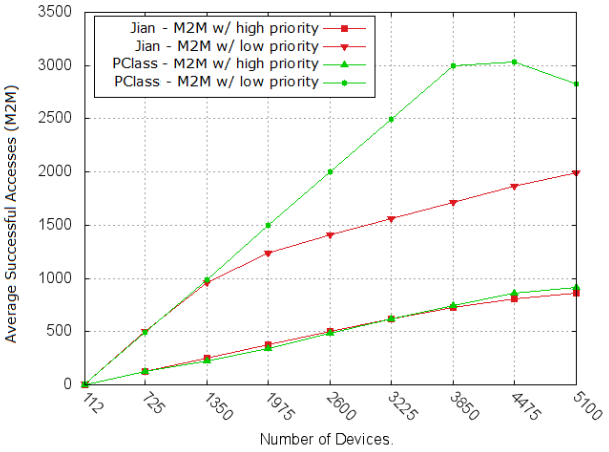

Figure 9. Average Succesful Access - M2M Devices of High and Low Priority.

4) Preamble Transmission: The average number of preamble transmission retries shown in Figures 11 and 10 is directly related with the power consuming. Once radio transition activity demands a significant amount of power, when more preambles are transmitted more energy is consumed. The decreases shown in Figure 10 in the number of preambles at 2600 to 5100 devices is related with the network congestion. Since more devices are trying to access, less preambles will be transmitted by the PClass. Depending on the application type, devices can use batteries as their primary energy source. However, as the number of devices and the type of application grow, it becomes clearer that the management of energy resources is an important aspect for feasibility of some applications (e.g., environment monitoring, smart cities, etc). Thereby, energy awareness strategies play an important role in this process. Our proposal considers the energy aspect to keep the number of preamble transmission lower than other proposed approaches, see Figure 10.

In our proposal, the preamble transmission is controlled by blocking the access request of devices. As illustrated in Figure 11, in our approach the H2H devices show a lower performance when compared to Jian algorithm. However, since the expected number of M2M devices is higher than H2H devices, our proposal causes less impact over the network than Jian algorithm. Furthermore, energy consumption is a more important issue when related to autonomous devices (M2M) than non-autonomous ones (H2H).

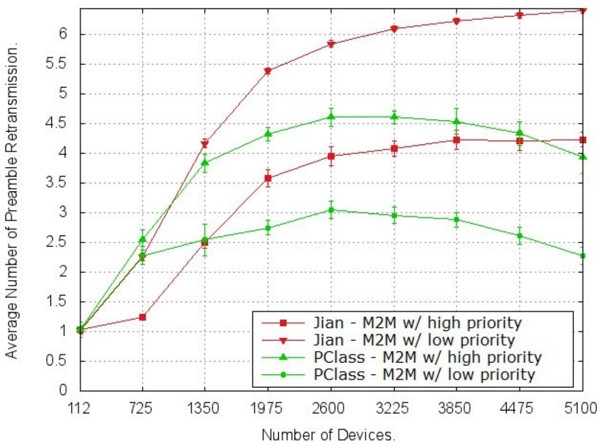

Figure 10. Average Preamble Transmission - M2M Devices.

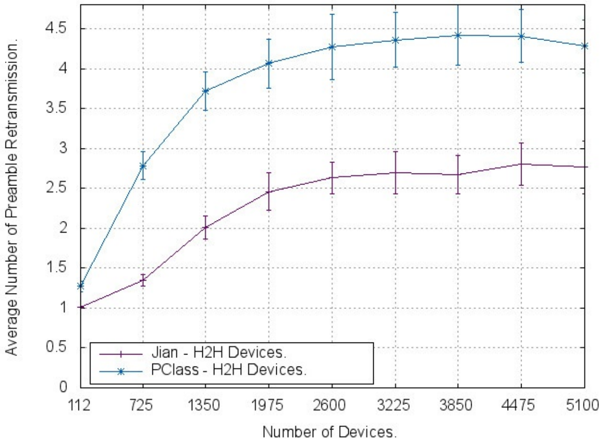

Figure 11. Average Preamble Transmission - H2H Devices.

VI. CONCLUSION AND FUTURE WORKS

In this paper, we have presented a new congestion control approach for LTE that can reduce the impact over the H2H devices and establishes priorities amongst M2M devices using classes of priorities. Besides, the proposed mechanism can mitigate the impact of M2M devices in the LTE networks and presents a low implementation complexity. In this context, our approach shows a good result when compared with the others in the literature. From the analysis of the results obtained by simulations, we observe that our approach to change the probability of both access and backoff time (as a strategy to differentiate the priorities between M2M and H2H classes and amongst M2M classes) can mitigate the impact of congestion caused by excessive M2M devices on LTE network. We have observed also that our approach to identify the congestion level (as low, medium, and high in the RAN of LTE network), in the base station constraints the amount of devices that can successfully access the base station.

REFERENCES

[1] A. M. Maia, M. F. d. Castro, D. Vieira, and Y. Ghamri-Doudane, "Toward a new lte uplink packet scheduler for machine-to-machine communication," in 2014 Brazilian Symposium on Computer Networks and Distributed Systems, May 2014, pp. 122–129.

[2] Y. Chang, C. Zhou, and O. Bulakci, "Coordinated random access management for network overload avoidance in cellular machine-to-machine communications," in European Wireless 2014; 20th European Wireless Conference; Proceedings of. VDE, 2014, pp. 1–6.

[3] E. Dahlman, S. Parkvall, and J. Skold, 4G: LTE/LTE-advanced for mobile broadband. Academic press, 2013.

[4] 3GPP. http://www.3gpp.org/about-3gpp/about-3gpp. [Online; retrived March 19, 2017].

[5] K. Zheng, S. Ou, J. Alonso-Zarate, M. Dohler, F. Liu, and H. Zhu, "Challenges of massive access in highly dense lte-advanced networks with machine-to-machine communications," Wireless Communications, IEEE, vol. 21, no. 3, 2014, pp. 12–18.

[6] T.-M. Lin, C.-H. Lee, J.-P. Cheng, and W.-T. Chen, "Prada: Prioritized random access with dynamic access barring for mtc in 3gpp lte-a networks," Vehicular Technology, IEEE Transactions on, vol. 63, no. 5, Jun 2014, pp. 2467–2472.

[7] K.-D. Lee, S. Kim, and B. Yi, "Throughput comparison of random access methods for m2m service over lte networks," in GLOBECOM Workshops (GC Wkshps), 2011 IEEE. IEEE, 2011, pp. 373–377.

[8] S.-Y. Lien, T.-H. Liau, C.-Y. Kao, and K.-C. Chen, "Cooperative access class barring for machine-to-machine communications," Wireless Communications, IEEE Transactions on, vol. 11, no. 1, January 2012, pp. 27–32.

[9] 3GPP, "Service requirements for machine-type communications (mtc)," 3GPP, Tech. Rep., 2013.

[10] B. Yang, G. Zhu, W. Wu, and Y. Gao, "M2m access performance in lte-a system," Transactions on Emerging Telecommunications Technologies, vol. 25, no. 1, 2014, pp. 3–10.

[11] X. Jian, Y. Jia, X. Zeng, and J. Yang, "A novel class-dependent back-off scheme for machine type communication in lte systems," in Wireless and Optical Communication Conference (WOCC), 2013 22nd. IEEE, 2013, pp. 135–140.

[12] M. Hasan, E. Hossain, and D. Niyato, "Random access for machine-to-machine communication in lte-advanced networks: issues and approaches," Communications Magazine, IEEE, vol. 51, no. 6, 2013.

[13] A. Lo, Y. W. Law, M. Jacobsson, and M. Kucharzak, "Enhanced lte-advanced random-access mechanism for massive machine-to-machine (m2m) communications," in 27th World Wireless Research Forum (WWRF) Meeting, 2011, pp. 1–5.

[14] J.-L. Chen, H.-C. Hsieh, and Y. Larosa, "Congestion control optimization of m2m in lte networks," in Advanced Communication Technology (ICACT), 2013 15th International Conference on, Jan 2013, pp. 823–827.

[15] A. Laya, L. Alonso, and J. Alonso-Zarate, "Is the random access channel of lte and lte-a suitable for m2m communications? a survey of alternatives," Communications Surveys Tutorials, IEEE, vol. 16, no. 1, First 2014, pp. 4–16.

[16] U. Phuyal, A. T. Koc, M.-H. Fong, and R. Vannithamby, "Controlling access overload and signaling congestion in m2m networks," in Signals, Systems and Computers (ASILOMAR), 2012 Conference Record of the Forty Sixth Asilomar Conference on. IEEE, 2012, pp. 591–595.

[17] 3GPP, "Study on ran improvements for machine-type communication," 3GPP, Tech. Rep., 2014.

[18] M.-Y. Cheng, G.-Y. Lin, H.-Y. Wei, and C.-C. Hsu, "Performance evaluation of radio access network overloading from machine type communications in lte-a networks," in Wireless Communications and Networking Conference Workshops (WCNCW), 2012 IEEE. IEEE, 2012, pp. 248–252.

[19] The network simulator - NS-3. http://www.nsnam.org. [Online; retrived April 10, 2017].

[20] ZTE, "Backoff enhancements for ran overload control," 3GPP, Tech. Rep., 2011.