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Adaptive Congestion Control for Massive Machine Type Communications in Cellular Network

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***Abstract*—The ubiquitous deployment of massive Machine-Type Communication (mMTC) devices and the traffic diversity of the various IoT applications challenge the network efficiency. It suffers Congestion and signaling overload due to the high probability of collisions, especially in a dense network scenario. In this paper, we propose an adaptive grouping and strategy for the mMTC devices capable of reducing the number of simultaneous transmissions. Hence guarantee the successful transmission of the data in the 5G cellular network.**

***Index Terms*—mMTC, 3GPP, Grouping; 5G Network, ID sharing; IoT; Overload, Scheduling, Network congestion.**

I. Introduction

In the massive machine type communication (mMTC) scenario, high connection density is needed to support a tremendous number of devices with zero/very low mobility transmitting occasionally in the network at a low bit rate. Providing guaranteed network access to these devices represents a challenge for the network operators as the network will suffer for high MAC signaling overhead affecting the mMTC device's energy efficiency characteristic [1]. The high number of collisions in the contention-based random access procedure is surely leading to a failure of some mission-critical services such as environmental monitoring alarm and eHeath.

Hence the need for an efficient load control mechanism to guarantee successful data transmission.

Existing solutions to resolve the above issue focus on either streamlining messaging processes [2] sharing limited resources [3], forming device groups is one of the most effective techniques for the implementation of overload control schemes. Coleman in [4] highlights some physical and medium access techniques to address the problem of a massive number of access attempts mMTC devices in the 5G network.

Our approach takes full advantage of the application-to-device relationship to enhance the grouping mechanism. By transforming applications into *task execution* followed by sequential device triggering, our algorithm performs the grouping on the task level to reduce the signaling overload created as each member of the group. In other words, our grouping strategy will reduce the collision rate significantly.

II. mMTc RACH Procedure in 5G Network

5G is the fifth generation of wireless communications technologies supporting cellular data networks. It is characterized by some critical enhancements on the cellular network such as eMBB (enhanced Mobile Broadband), mMTC (massive Machine Type Communications), URLLC (Ultra-Reliable Low Latency Communications).

1) State of the art of mMTC: The mMTC devices transmit small packet sizes of data following two traffic patterns: **Periodical**: Triggered as a Mobile Autonomous Reporting up-link transmission for applications such as smart grid [5]. **Event-driven**: Triggered by emergency events such applications include smoke alarm detectors, disaster alert. Those devices are characterized by features such as Energy efficiency, low complexity, and wide coverage.

2) RACH Procedure in 5G network: In the current Network scenario, UE performs the random access procedure as the initial contact between UE and the base station. As shown in Figure 1, It exists two types of random access procedure: contention-based and contention-free.

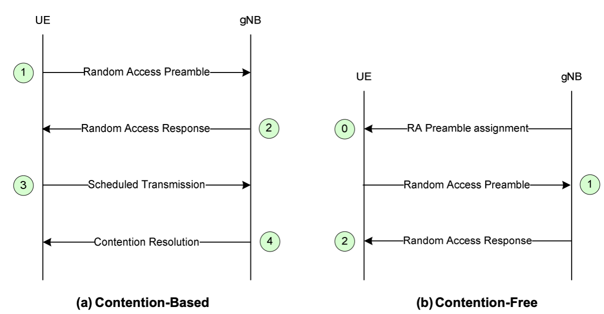

Fig. 1. Random Access Procedure in 5G Network [6]

III. Problem Formulation

The problem is formulated as a network where a set of mMTC devices triggered by some applications need to access the network. They perform the tasks and report to the application server before the expiration time of the application.

Considering the simultaneous RACH procedure attempts, the expiration time of each application, and the number of tasks they may contain; any collision or delay during the RACH procedure side will affect the success probability of the data transmission. The objective is to group the devices in such a way that all tasks can be executed with the required time-frame preventing any failure. Hence the need to minimize the total number groups by optimally placing the right device in the group. The formulation is a variation of the *1D bin*

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packing problem. Devices and groups are an analogy to objects and bins; latency constraints of applications reflect bin sizes. As a combinatorial optimization problem, it is NP-hard.

IV. Proposed Grouping scheme

Our proposed algorithm is a modified version of the Best Fit Decreasing algorithm (BFD) [7] to effectively group MTC devices while respecting application latency requirements.

We integrated the scheduling mechanism by sorting in increasing order the application's time constraint. The grouping process starts by sorting devices in descending order of their weight and assigned to a group one-by-one. Once grouped, the devices linked to a certain number of tasks in a group are then scheduled in the order of corresponding application's expiration time, so that a task related to the most urgent application can be executed first. The algorithm evaluates the device-dependent space of each group for all related applications. A device joins a group that has space to accommodate it with minimum remaining space. If there is no group with enough space to accommodate the device, a new group is created. It runs iteratively till all devices are grouped.

Algorithm 1 Pseudo-code of the modified BFD Algorithm

```
Sort all devices in decreasing order of their weighting time T_n
P = {∅}
foreach j : j ∈ N do
    foreach m : m ∈ M do
        Find a group i ∈ P that remaining space of group
        τ_m · γ − Σ_j T_j · g_{i,j} is the minimum
    end
    if i ≠ {∅} then
        j ∈ i
    else
        Create a new group : i' ∈ P   j ∈ i'
    end
end
```

To prevent any frequent re-grouping, we introduce a relaxing factor γ is introduced to control the extension of final bin sizes. Therefore, applications are assumed to begin concurrently when grouping; The time constraint becomes $\gamma \cdot \tau_m$ for further adjustment. The notion of ***miss rate*** is then added the ratio of tasks executed after $\gamma \cdot \tau_m$.

V. Performance Analysis

The simulation setup is presented as a town of 1000 to 5000 households having smart devices provided by utility companies. These devices collect, compute, record, and transfer resource consumption data on demands from the company responsible for applications such as monitoring and billing for major simulation parameters are listed in ***Table I.***

The required number of groups and task missing rates are considered as the major performance indicator (KPI).
It is observed in ***Table II*** that when the packing factor γ increases, the time constraint is relaxed, more devices can be assigned to the groups. It is worth mentioning that our BFD algorithm can support massive devices. The gap between the number of devices per group is small regardless of the number of devices (from 1000 devices to 5000). There are nearly 28 devices in each group and the miss rate is nearly 6%.

TABLE I
Simulation Parameters

Parameter	Description	Value
N	# of devices	1000 to 5000
K	# of different tasks	10 and 40
	Tasks per application	1 to 5 , uniform distribution
	Tasks per device	1, 3, 5 , uniform distribution
M	# of applications	20
τ_m	application's time constraint	0.2% of inter arrival time
$\frac{1}{\lambda_m}$	Mean of application inter-arrival time	30 mins(5%), 1 hours(15%), 2 h (40%), 24 h(40%) [5]
t	Task time	uniform(0.1,0.2) s

TABLE II
BFD performance with varying packing factor γ in device per groups(DpG) , tasks=10.

Devices	DpG (γ= 0.3)	Miss (%)	DpG (γ= 0.7)	Miss (%)	DpG (γ= 1.1)	Miss (%)
1000	7.77	0	17.61	0.28	29.67	5.95
2000	7.14	0	18.35	0.01	27.04	6.00
3000	7.97	0	17.79	0.49	29.22	6.30
4000	7.57	0	18.03	0.54	28.11	5.89
5000	7.30	0	17.40	0.57	28.55	6.66

VI. Conclusion

In this paper, we propose a grouping algorithm to deal with the congestion problem by finding the best grouping solution to minimize the number of simultaneous transmission in the context of massive MTC devices in a 5G network. The obtained results clearly illustrate the grouping performance of our proposed algorithm and its impact on groups by lowering the miss rate probability in each group. Comparisons with other grouping strategies will be presented in our future work.

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