REDUCING ACCESS DELAY IN MACHINE TO MACHINE WIRELESS COMMUNICATION OVER LTE

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***Abstract* – Machine type communication is the new buzz in 4th generation mobile technology. Trillions of machines are deployed under one base station and they try to access the network in random fashion. Handling so many devices is a big problem and it needs proper solution to avoid overloading of the network. Third generation partnership project (3GPP) has suggested a method called access class barring but that is not sufficient. This paper suggests a new method called co-operative access class barring which provides better result than ACB.**

I.INTRODUCTION

Machine type communication is a new technique of communication in which communication takes place without any human intervention. This is also called as internet of things. Devices used in this method are called machine type communication devices (MTC device).This communication method is going to play a big role in our day to day life.MTC devices can be used in vehicles, smart grid, smart city etc.

MTC devices are small in size and they carry very small data(in Kb) but they are deployed in huge quantity and they use already deployed network. These devices access the network only when they have some important data generated otherwise they remain in silent mode and unattached with the base station this method of access is random in nature. As we know that band width is a very limited re-source and should be used in judicial way. Installing a separate network for machine type communication cannot be an economical choice. So it is advised to use the already deployed communication network like WiMax and LTE-Advanced. This network should be able to handle the large number of MTC devices. Large number of MTC devices can cause congestion in the network. Congestion can occur due to simultaneous signalling messages from MTC devices. For example if many MTC devices detect an event at the same time they will try to access the network which can cause the congestion of the network. Now the problem is how to handle the traffic which is already congested by voice, video calling, internet access and other services.

To avoid congestion, few methods such as multiple access collision avoidance (MACA) based solution have been suggested for MTC devices but these schemes are effective for contention based data delivery and they are not suitable for the cellular network where contention is used for request delivery while data is transmitted in scheduling basis. A stabilization method is used in RACH to control the expected number of simultaneous accesses to a common RACH radio resource to be one .Stabilization maximizes the throughput and enhances the delay performance of request delivery via RACH.

Third generation partnership project (3GPP) has suggested a method called access class barring (ACB) to avoid congestion. In this method, base station broadcasts an ACB parameter p € [0,1] to MTC devices. Each active MTC devices (devices which are trying to send a request to the BS) also draws a number q € [0, 1]. If q≤ p then active MTC device proceeds to the random access procedure otherwise it is barred for a barring time period.

In the present cellular network each active device is attached to only one base station. In LTE-advanced, active MTC device can only send access requests to the base station to which MTC device is attached to. In the ordinary ACB each BS determines the ACB parameter p for the individual stabilization in each cell. When severe congestion occurs in a cell, the BS may set its ACB parameter p to an extremely low value which results in unacceptable access delay. This method fails to handle the congestion.

The state–of-the –art cellular system, such as LTE advanced uses multi-tier network architecture. It has macrocells and picocells, there are picocells underlying macrocells to improve the received signal strength and to reduce the burden of the macrocells. An MTC device can be located in the overlapped coverage areas of macrocell and picocells, this MTC device can access the base station even during congestion.ACB parameter p is a key factor for controlling the congestion. In the proposed method ACB parameter p is jointly decided by all the base stations based on the level of congestion. In this way problem of congestion is solved. In LTE-A, base stations are connected by X2 interface, so direct communication between base stations is possible.

II. PROBLEM FORMULATION:

Access delay can be denoted by AD, for any user equipment UE i is the time in ms from when the user equipment starts the random access procedure until the time when UE gets the access. Let Ts be the time when UE wants to start the random access procedure and let Ta be the time when the UE has been granted access by the eNB. The access delay can be calculated as

$$AD = Ts - Ta$$

Access delay plays a very important role to perform the random access procedure. Contention based random access procedure in LTE-Advance is undermentioned in fig 1.It follows four steps

- Random access Preamble: Each UE randomly selects a preamble from the contention based group and transmits it nearby eNB.
- Random Access Response: The eNB correlates all possible preambles in each random access opportunity with the received preamble. The eNB assigns uplink channel.
- Scheduled Transmission: MTC nodes transmits unique identity with the allocated uplink resource.
- Contention Resolution :More than one MTC which nodes which had sent the same preamble may response, so the eNB will not be able to identify between different nodes and they will follow step 1.

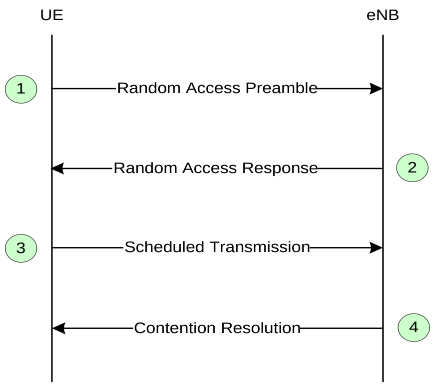


Fig 1.: Random Access Procedure

Consider the random access of M2M communications in LTE-Advanced with M BSs indexed by m= 1,2……. and N active MTC devices indexed by n = 1,2……Distinct from ordinary ACB that each MTC device can only access the BS attached by the MTC device, it is proposed that an MTC device is able to access the BS unattached by the MTC device when the MTC device locates within the overlapped coverage area of multiple BSs.

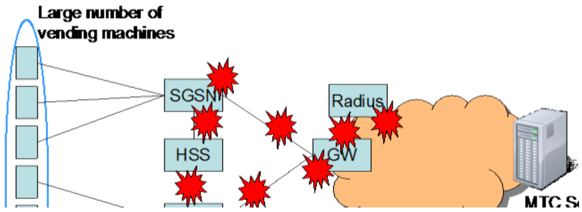


Fig.2: Signaling network congestion

(i) Let Am be the set of MTC devices attaching to the mth base station and ‖ Am ‖ be the norm of Am, ∑ ‖ Am ‖ = N

(ii) Let Mn be the set of BS that nth MTC device can possibly access. The nth MTC device selects one BS from Mn to follow random access procedure.

(iii) Denote Nm as the set of MTC devices that access the mth BS .In normal ACB ‖ Nm ‖ for all m are known by all BS.If each MTC device can access the base station unattached by the MTC device, ‖ Nm ‖for all m are are random variables not known by BSs.

(iv) Denote In,m as indicator function for nth MTC device,

In,m = {1,if mth base stn is within Mn

0,otherwise (1)

In normal ACB the throughput of each cell can be individually maximize by setting Pm= 1/‖Nm‖(here Pm is the ACB parameter of the mth BS),the delay experienced by an MTC device attached to the mth BS may be unacceptable when Pm requires to be set to an extremely small value under large ‖ Nm ‖.Such abnormal condition cannot be improved by normal ACB.Main objective of this paper is to device a method which can control the ACB parameters P=[p1,p2,p3……….pM] decided jointly by M BSs to minimize the largest access delay faced by N active MTC devices. This objective can be achieved by minimizing the maximum number of accesses among M BS. Cooperation among BSs jointly decides the value of P= [p1,p2……………pM].It can be expressed as

$$\min_{P1,P2\ldots PM} \max (\| N1 \|, \| N2 \|, \ldots\ldots\ldots\ldots \| NM \|) \quad (2)$$

Here two conditions should be fulfilled:

(i) $0 \leq P = [P1, P2, \ldots\ldots\ldots\ldots PM] \leq 1$ and
(ii) $\|Nm\| Pm \leq 1$, for m = 1,2……………M

Equation (2) minimizes the total number of access to the BS under severe congestion, and also follows the conditions. Mathematically condition (ii) can be relaxed to $\|Nm\| Pm \leq 1+\delta$. for m =1,2……..M (3)

Its performance still remains the same till the time δ is very small. As per equation (2) each MTC device is able to access BSs which are not attached by MTC, according to our proposition $\|Nm\|$ for all m are random variables and not known by the base stations. To get $\|Nm\|$ for all m ,BS should be aware of the strategy adopted by each MTC device on the selection of the BS in any given p. Now BS can optimize the number of access of MTC device by controlling P. In the next section base selection strategy for each MTC device is proposed. All MTC devices are homogenous and there is no priority among them.

III. BASE STATION SELECTION METHOD

Assume that a set of ACB parameters Pn = {pi, pj,…….pk € p, here $\| pn \| = \| Mn \|$ is received by nth MTC device. Denote Pn,x is the probability that nth MTC device selects the xth base station. Since there is no priority among MTC device, no MTC device can make decision. In the next stage, constraints for nth MTC device on the selection of one base station from Mn BS are explained.

Proposition 1. Consider $pi \geq pj \geq \ldots\ldots\ldots\ldots \geq pk$, the strategy adopted by the nth MTC device should satisfy that Bn (pi, pj, …….pk) = [Pn,i ,Pn,j ,….Pn,k], where $Pn,i \geq Pn,j \geq \ldots Pn,k$ and $\sum Pn,x = 1$, (4)

Proof: Consider the case of Pn which has only two elements pi and pj ,and $pi \geq pj$.All the MTC devices receiving pi and pj adopt the same strategy and the MTC device experiences that there are MTC devices adopting the same adopting the same technique with it. Now if the MTC device adopts the strategy with $Pn,i \leq Pn,j$, the jth BS with severe congestion suffers even more congestion because all MTC devices receiving pi and pj tries to access jth base station ,on the other hand the slight congestion of the ith base station is eased more. Hence adopting $Pn,i \leq Pn,j$ may not improve the access delay of the MTC device. On the other hand when $Pn,i \geq Pn,j$ is adopted the performance is improved. If pi = pj,MTC device selects any one BS and Pn,i = Pn,j is adopted.

Proposition 2. When $pi \geq pj \geq \ldots\ldots pk \geq 0$ then nth MTC device adopts a mixed strategy-

Bn (pi, pj, ……….pk) = [Pn,i ,Pn,j ,……….Pn,k], where $Pn,i \geq Pn,j \geq \ldots Pn,k \geq 0$ and $\sum Pn,x = 1$, (5)

Proof: Two element method is also adopted in this metod, pi > pj and Pn,i > Pn,j while Pn,j = 0 then Pn,i = 1 for the MTC device and also for other MTC device receiving pi > pj (pure strategy) .If we adopt the pure strategy ,congestion in jth BS can be relaxed but congestion in ith BS may become worst.Now MTC device change their strategy and Pn,i > Pn,j is adopted which suggests for a mix strategy.

Proposition 3.A general form of selection strategy can be given as

Bn (pi, pj, …………...pk) = [Pn,i = $pi / \sum p x$, Pn,j = $pj/ \sum p x$,…… Pn,k = $pk/ \sum p x$, x € Mn (6)

At this level the base selection strategy is known by all of the MTC devices, now BSs can control p to jointly achieve the stabilization and reduce access delay. In the next section the cooperative access class barring is proposed to optimize the joint probability p.

IV. COPERATIVE ACCESS CLASS BARRING

Once the base selection strategy is known by all BSs, $\| Nm \|$ for all m can be obtained by

$$\| Nm \| = \sum_{x=1}^{M} \sum_{n \in Ax} In,m\, Pn,m \text{ for } m = 1,2\ldots M \quad (7)$$

We can see here that $\| Nm \|$ is no longer unknown by BS and equation (2) can be written as

M

Min max (∑ ∑ In,1 Pn,1, ..∑ ∑In,M Pn,M) P1,P2…PM

x=1 n € Ax (8)

Such that 0 ≤ P= [P1,P2,……PM] ≤ 1 satisfied and

∑ ∑ In,1 Pn,1 ≤ 1 +σ

∑ ∑ In,2 Pn,2 ≤ 1 +σ (9)

∑ ∑ In,M Pn,M ≤ 1 +σ

Equation (9) is not solvable directly, we follow an iteration method consisting of two algorithm to solve it. Algorithm 1 is proposed to obtain ‖ N1*‖, ‖N2* ‖,………… ‖ NM* ‖ in a given deployment of BS and MTC devices such that differences among ‖ N1*‖, ‖N2* ‖,………… ‖ NM* ‖ are minimized .Still the optimum p is unknown ,so algorithm 2 is devoted to obtain optimum p.

Algorithm 1: THE PROCEDURE OF OBTAINING ‖ N1*‖, ‖N2* ‖,………… ‖ NM* ‖

1. Set ‖ Nm* ‖ = ‖ Nm'‖ for all m
2. Find the BSs with minimum ‖ Nm* ‖, m' = arg min { ‖ N1*‖, ‖N2* ‖,………… ‖ NM* ‖ } ,Find the BSs with second minimum ‖ Nm* ‖, m''= arg m''≠ m' min { ‖ N1*‖, ‖N2* ‖,………… ‖ NM* ‖ }.Denote Lm'as the number of MTC devices that n € N'm'and m' € Mn for all possible m'.
3. If Lm'= 0 then
4. Move ‖ N*m'‖ to the output queue and the BS is not considered in the next operations.
5. Goto "Row 2" .
6. end if
7. if Lm' ≤ ∑ (‖ N*m'' ‖ - ‖ N*m' ‖) for all possible m' then
8. Set ‖ N*m'' ‖ = ‖ N*m' ‖ for all m'
9. Set Lm' = Lm' - ∑ (‖ N*m'' ‖ - ‖ N*m' ‖) .
10. else
11. Equally allocate Lm' to all possible m'.
12. Set Lm' = 0
13. Move ‖ Nm'‖ to the output queue and this BS is not considered in the next operations.
14. end if
15. Goto " Row 2" until all ‖ N1*‖, ‖N2* ‖,………… ‖ NM* ‖ are within output queue.
16. Output: ‖ N1*‖, ‖N2* ‖,………… ‖ NM* ‖

At this moment optimum p is still not known, Algorithm 2 is developed to obtain the optimum p so that ‖ N1‖, ‖N2 ‖,………… ‖ NM ‖ is also optimum. Algorithm 2 stops when the difference of results between two iterations is not larger than ε. The number of iterations is acceptable for smaller value of ε like 0.0001.

Algorithm 2 Optimization of p

1. Input ‖ N1*‖, ‖N2* ‖,………… ‖ NM* ‖ from algorithm 1.
2. Set pm = 1/ ‖ N*m‖, for all m.
3. Set ‖N'm‖ = ∑ ∑ In,m Qn,m for all m
4. while ‖ N'1‖ -‖ N*1‖ > € or ‖ N'2‖ -‖ N*2‖ > € or …….or ‖ N'M‖ -‖ N*M‖ > €
5. Set ‖ N*m‖ = ‖N'm‖ for all m
6. Set pm = 1/ ‖ N*m‖ for all m
7. Set ‖N'm‖ = ∑ ∑ In,m Qn,m for all m
8. end while
9. output p1,p2……………..pM

V. SIMULATION RESULT

In the proposed method ,simulation parameters for LTE MTC devices have been used that is also recommended by 3GPP.In this method seven hexagonal macrocells and three picocells have been used. Picocells are used at the place where traffic load is more and covers around 20% of the total MTC devices. Table I is given below which gives details of the simulation parameter.

This method evaluates following traffic parameters: (1) Average access delay and the average throughput.(2) the worst case delay and worst case throughput. Average access delay is a very important parameter which required by system provider and the worst case delay is useful for MTC device user.

The average delay is calculated by adding total delay of MTC devices then dividing it by the total number of MTC device. The worst case delay is the largest delay among MTC devices. Fig 4 indicates average delay and worst case delay for proposed method as well as ordinary method. Result indicates that around 30% improvement can be achieved by using proposed method which is a very good improvement in access delay. This improvement is achieved because MTC devices can access the BS not attached by the MTC devices

TABLE I : SIMULATION PARAMETERS

Parameters	Assumptions
Total number of MTC devices	10000,20000,30000,40000,50 000
Number of cells	Seven Macrocell and three picocell
Cell layout	hexagonal
Inter-site distance	500 m
MTCdevice deployment	Picocell covers 20%,macrocell covers 6%,Central macrocell covers 4%
Number of preambles	one preamble
The period of RACH	5 ms
Downlink transmit power of the BS in the macrocell	45dBm
Downlink transmit power of the BS in the picocell	30dBm

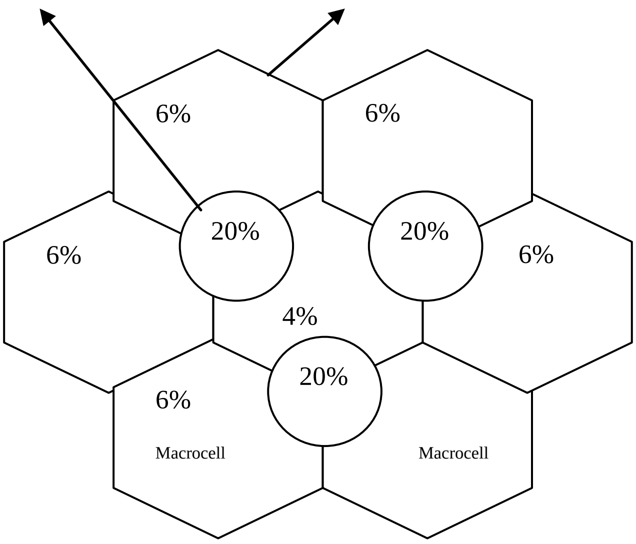
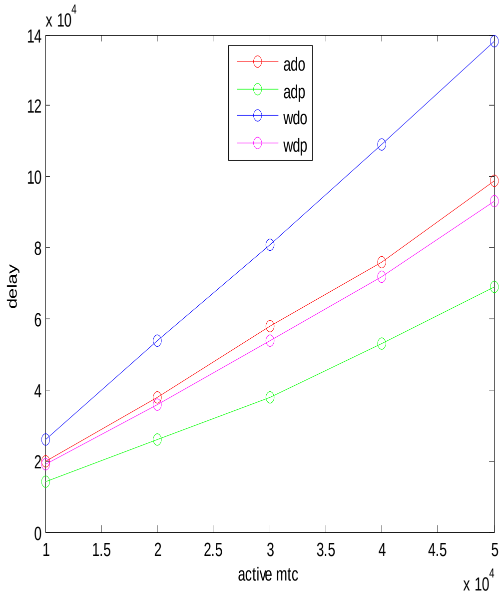


Fig. 3: Hexagonal Cell Layout



ado: average delay ordinary
adp: average delay proposed
wdo: worst delay ordinary
wdp: worst delay proposed

Fig. 4: The average delay and worst case delay.

VI. CONCLUSION

This paper fids a solution to reduces access delay for MTC devices in turn it reduces the congestion and avoids overloading of the MTC network. Ordinary ACB method uses only one cell, so it fails during overloading of the network on the other hand proposed method uses cooperative ACB so it handles the traffic smoothly.

VII. REFERENCES

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