Energy-Efficient MAC Layer Protocol for Communication

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Abstract - *Machine-to-Machine Communication (M2M) is communication between wireless devices which one of application is the Internet of Things. M2M is growing fast and implemented in many areas. In most cases they are powered by the cell which needs frequent replacement, it is the costly process also in most of the case it interrupts the working of the device. So, it is a wise decision to optimize the power consumption of the M2M device for better reliability and cost-saving. For that, one of the ways is to implementation of a low power MAC protocol in the device. The related works have indicated that idle listening and collisions are the main sources of power waste.*

The paper focus on the energy-efficient MAC protocol design, various methods that would help to preserve energy are considered. Furthermore, a hybrid energy-efficient MAC protocol is designed for M2M communications. The technique used for the MAC protocol design is clustering which reduces the energy consumption by the nodes to communicate with other nodes effectively.

Key Words: M2M, Clustering, Energy efficient, Mac Layer, Matlab

1. INTRODUCTION

M2M or machine-to-machine technology is a term that is used to describe two or more devices or machines that can talk to each other. Technological advances in recent years have enabled the production and deployment of ubiquitous communication devices that replace traditional human-controlled operations with automated machine-to-machine (M2M) communication. This trend has spun significant interest from industry and the research community. The number of M2M enabled devices is increasing exponentially and forecasted to grow from 50 million in 2008 to well over 200 million in 2014 and 50 billion by 2020 [1]. Here, M2M enabled device means any machine that can capture an event or generate data by itself and then transmit the information to other devices through wired or wireless.

Along with its many perks, the major detriment in M2M communications is that its unique characteristics also introduce several networking challenges. As it includes a large number of devices and fundamental issue is efficient management of the network. It also has to consider the traffic characteristics and cater to the quality of service (QoS) requirements. Also, the service requirements of applications using M2M communication may be different from the existing application and will also vary within M2M based application. As M2M communication is primarily "hand-off" (i.e. free from human intervention), this communication network must be self-capable in various aspects such as organization, configuration, and healing [2]. These requirements and characteristics affect all the layers in the network stack and make network support for M2M communication a challenging area of research at a different level.

1.1 Background

Machine-to-Machine (M2M) communication, also known as Machine-Type Communication (MTC), is generally defined as the ability of machines to communicate without human interventions. It is one of the newly developed communication technologies with fast-growing in recent years, which can be widely applied in many areas. Especially for the implementation of the Internet of Things (IoT), M2M communications in cellular networks are seen as one of the most important approaches and enablers. M2M systems are supposed to support a huge number of nodes and be capable of autonomous operation and self-organization [2].

1.2 Organization of report

The project was completed using various steps, some of the major steps are as follows:

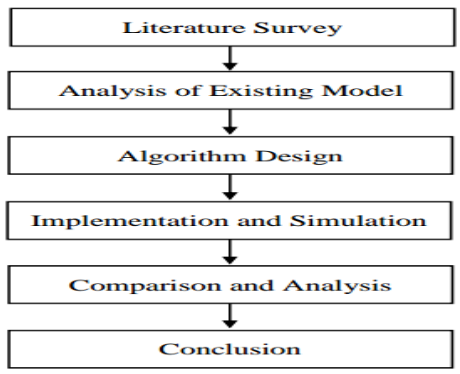


Figure 1:- Flow Diagram

2. **Proposed Algorithm**

An algorithm was developed and applied to ensure the protocol design with the energy-efficient scheme as its main priority. After the algorithm was designed the network architecture was also assumed and created virtually in the simulation software.

The applied algorithm and the network architecture were simulated and analyzed. The results obtained from the proposed design were compared with the existing normal case scenario and a conclusion was drawn based on the results obtained.

In reality, the test of the design involves a complicated procedure of collaboration between the real base station and machine nodes, which is expensive and impractical to repeat many times. This problem has been easily solved by simulation tools. MATLAB is such a simulation platform professional in many fields of communications. It has an excellent ability in matrix computation, which is suitable for this research work.

The accomplished part of the project can be categorized mainly into the following phases and the algorithm used in phases is explained below.

Phase 1: Broadcast Phase

i. In this phase, the energy status of the node, its ID, position, distance from the base station, and power received from the base station are measured.

ii. Node with received power greater than the threshold is given the status 'NI' and lesser than the threshold received power is given the status 'NO'.

The pseudo code in for this phase is as follows.

for
k = 1 to number of nodes
energy status of node k = 10 J
ID of node = k;
X position of node k = random number from -1900 to 1900
Y position of node k = random number from -1900 to 1900
Distance from Base Station of node k = Distance formula with a position of BS as the origin
*Power Received by node k = Frii's Transmission formul*a
end
if *received power greater than the threshold node status is set as 'NI'*
else
node status is set as 'NO'
End

Phase 2: Cluster Formation Phase

i. A node with node status as 'NO' is taken and all its neighboring nodes within the range of 300 m are identified.

ii. Node broadcasts a message which has the information about its node id and received power to all of its neighboring nodes such that each node knows the id and the received power all other nodes within the distance of 300 m.

iii. Each node already has the information of its neighboring nodes. A single node can be a neighbor to different nodes with a cluster area of more than 300 m of radius.

iv. During cluster formation, none of the clusters should have common nodes.

v. Each cluster is a circle with a radius of 300 m.

The pseudo-code in MATLAB for this phase is as follows.

if node status is 'NO'
Measure the distance between two nodes with status 'NO'
if the distance is less than 300 m
The nodes are neighboring nodes
End

Phase 3: Cluster Head Selection Phase

i. After the cluster is formed, the cluster head is to be selected.

ii. The criteria for cluster head are that node with maximum received power.

iii. In each cluster, all nodes have the id and received power information of remaining nodes in the cluster and hence, the node with maximum received power is taken as the cluster head.

iv. Once the cluster head is selected, its status is set as 'H' and its members status is set as 'S' meaning cluster head is already selected.

The pseudo-code in MATLAB for this phase is as follows.

for the length of neighboring nodes of a node

Select the node with maximum received power from a base station

if the node has the status of not a cluster head and not a cluster member

Select that node as cluster head Set the status of all of its members as 'S' i.e. selected as a cluster member

end

end

Phase 4: Selection of Efficient Received Power (Threshold)

i. The proposed protocol is based on partial clustering.

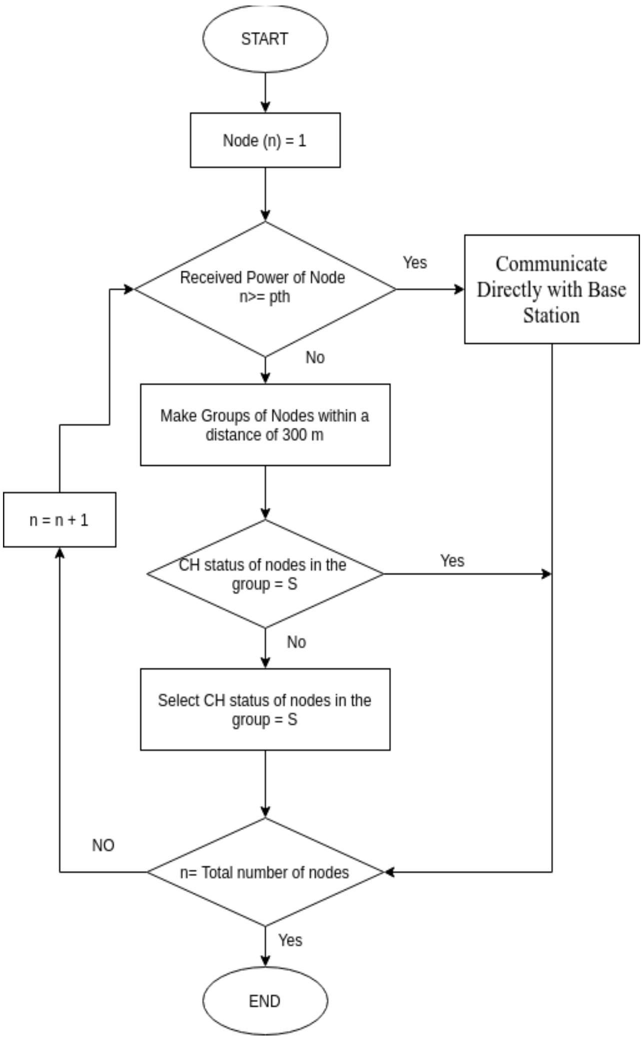
ii. In partial clustering, nodes with received powerless than the threshold are only clustered.

iii. The comparison in average energy loss in clustering with different thresholds was done.

iv. The experiments showed that efficient clustering was found to be in threshold received power of 2.5 milliwatts.

2.1. Flowchart of Clustering

The flowchart explaining the method applied for clustering is as follows**.**



The step-wise description of clustering is as follows:

i. The clustering process starts from node 1.

ii. The receiving power of the node is checked and if the received power is greater than the threshold received power then clustering is not required and node 1 can communicate directly with a base station. The node will have node status as 'NI' which means it is inside the threshold of received power and does not require clustering.

iii. When the received power is lesser than the threshold power then the node is required to be clustered, the node status is set 'NO' which means it outside the threshold of received power and requires clustering.

iv. The clustering is done in such a way that a group of nodes with status 'NO' within the range of 300 m is formed.

v. Initially, the cluster status of nodes is set to 'N' which means the cluster is not formed.

vi. After clustering, the cluster head is selected such that the cluster head has the minimum transmission energy to the base station or the highest received power from the base station.

vii. The status of a node which is cluster head is set to 'CH' and all of its members are set 'S' which means the cluster head is selected.

viii. In this way, the condition for each node is checked as the loop goes on and finally terminates after the last node.

3. Simulation

In the software simulation, a cell of 2000 m is taken and nodes are randomly distributed in the cell in the number 100 to 500. The base station is in the origin. The power transmitted by the base station to every node is taken as constant. All other parameters like antenna gain and losses are taken constantly for each node. The power received by each node is inversely proportional to the square of the distance between the nodes and the base station. Threshold power is assumed. Nodes received power greater than or equal to the threshold power communicate with the base station and other nodes with less power received from clusters. Nodes with less threshold received power are grouped in such a way that, a single node has neighboring nodes up to 300 m. Within one of such groups, the nodes with maximum received power are taken as cluster head, and other nodes within 300 m of distance communication with the cluster head. No nodes have two cluster heads at the same time. Cluster heads then communicate with the base station reducing the contention and avoiding the collision. It also reduces the direct transmission distance from nodes to the base station which reduces energy consumption.

3.1 Simulation Parameters

Different parameters are taken and others are assumed in the software simulation process. All parameters used are tabulated below.

Table -1: Sample Table format

Symbol	Parameter Name	Value
R	Cell Radius	2000 m
N_u	Number of Nodes	100 to 500
K^*	Constant	500
P_r	Received power by nodes	0.12 to 720 mw
P_{th}	Threshold power	0.5 to 7.5 mw
range	Cluster radius	300 m
d_{fbs}	Distance from the base station	0 to 2000 m
d_{fch}	Distance from Cluster head	0 t0 300 m
E_{elec}	Energy dissipation to run Tx and RX	50nJ/bit
E_{amp}	Transmit amplifier	100pJ/bit/m²

3.2 Proposed System Model

The system first considers an arbitrary area with a 2000m circular radius, i.e., only one cell is considered at this moment to verify our assumptions and results. The base station is assumed to be at the center surrounded by the mobile stations (not necessarily just a cell phone). The mobile stations are spread at random and change their position.

The scattered nodes are grouped into clusters using a partial clustering algorithm. It means that not all the nodes are clustered but the ones with certain criteria. In this case, the ones with the received power greater than the set threshold power (2.5 mW) are only clustered. Another important criterion for the nodes to be in a cluster is that they must be neighboring nodes within 300m range of each other. The clusters are formed based on similar powers of the nodes and a single node can only belong to one cluster at a particular time. The clusters only communicate with the cluster head rather than directly communicating with the base station. The cluster heads are selected based on the lowest transmission power.

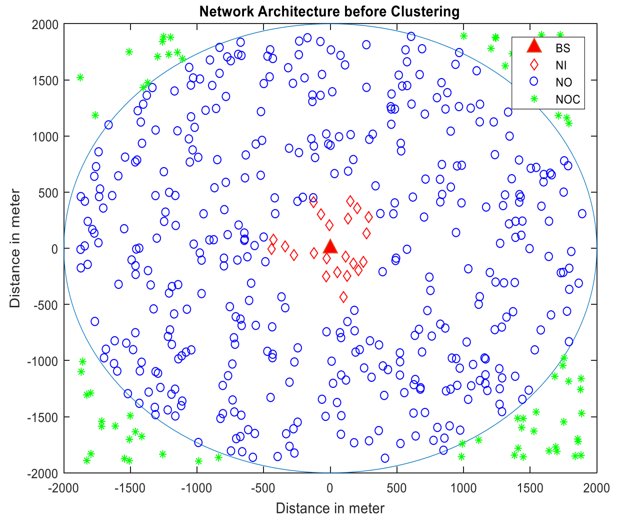


Figure 2: Network Architecture before clustering

The clusters that are formed communicate with the elected cluster head that communicated with the base station. So there are nodes that are not clustered as shown by the diamonds (Nodes inside the threshold power range) in the figure, the nodes that are clustered are shown in circles (NO nodes outside the threshold power), and the cluster heads shown in a filled circle (CH).

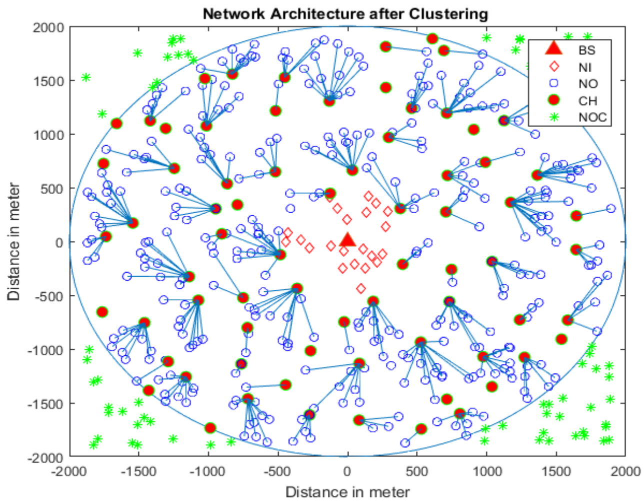


Figure 3: Network Architecture after clustering

3.3 System Analysis and Results

We can see from the graph and the tabulated exact data above, the performance of the clustered network has minimum energy consumption at 2.5mW. therefore, we have concluded that the best threshold for maximum system performance based on energy efficiency is 2.5mW. therefore, the entire clustering is done taking 2.5mW as the standard threshold for the designed network architecture. The comparison with the traditional non-clustered scheme is also done taking the clustering done using 2.5 mW as the threshold.

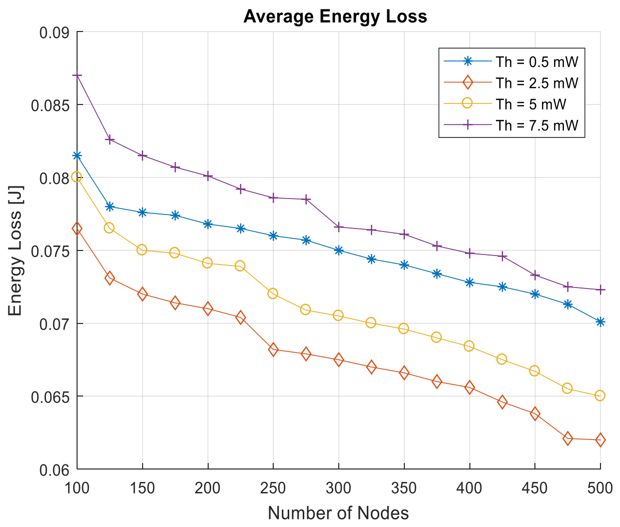


Figure 4: Energy Consumption at different threshold

Table 1: Tabulated Data of Energy Consumption at Different Threshold

S. N.	No. of Nodes	0.5mW	2.5mW	5.0mW	7.5mW
1	100	0.0815	0.0765	0.0800	0.0870
2	150	0.0776	0.0720	0.0750	0.0815
3	200	0.0768	0.0710	0.0741	0.0801
4	250	0.0760	0.0682	0.0720	0.0786
5	300	0.0750	0.0675	0.0705	0.0766
6	350	0.0740	0.0666	0.0696	0.0761
7	400	0.0728	0.0656	0.0684	0.0748
8	450	0.0720	0.0638	0.0667	0.0733
9	500	0.0701	0.0620	0.0650	0.0723

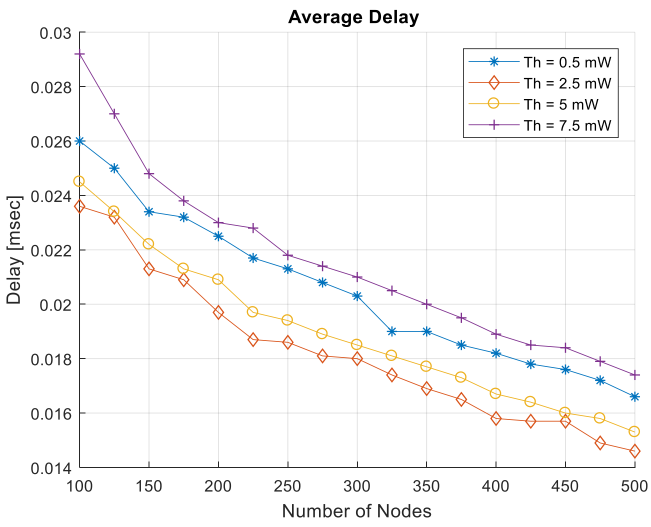


Figure 5: Energy Consumption at different threshold

As we can see from the above graph and the tabulated exact data above, the performance of the clustered network has a minimum transmission delay at 2.5mW. therefore, we have concluded that the best threshold for maximum system performance based on delay efficiency is 2.5mW. therefore, the entire clustering is done taking 2.5mW as the standard threshold for the designed network architecture.

3.2 Comparison of Outputs (Clustered vs Non-clustered)

The comparison with the traditional non-clustered scheme is also done taking the clustering done using 2.5 mW as the threshold.

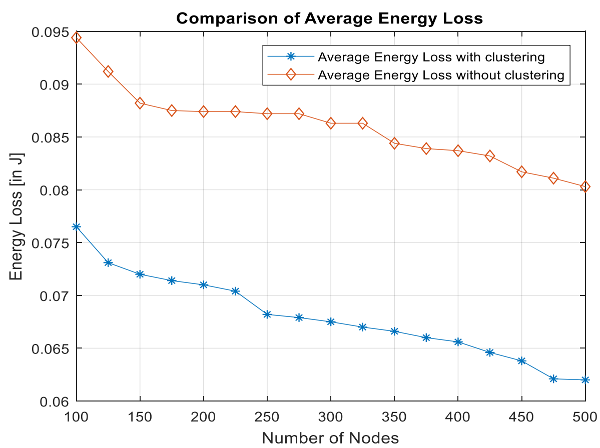


Figure 6: Comparison of Average Energy Loss(Clustered vs Non-clustered)

The output of our proposed model compared with the scenario of unclustered nodes and have concluded that the average energy consumption is decreased as a whole with the introduction of the clustering approach. Hence the development of a low-powered MAC protocol is achieved. The energy consumed as the no. of nodes increases is traced and tabulated below. The exact values of both the clustered and unclustered schemes are tabulated below for further analysis.

Table 2: Tabulated Data of Energy Consumption with and without Clustering

S.N.	No. of Nodes	Energy loss (clustered) in J	Energy loss (Non-clustered) in J
1	100	0.073	0.092
2	150	0.069	0.089
3	200	0.069	0.088
4	250	0.067	0.086
5	300	0.065	0.085
6	350	0.066	0.085
7	400	0.064	0.084
8	450	0.061	0.081
9	500	0.060	0.075

CONCLUSION

The M2M communication is undeniably one of the preeminent topics of the current generation that is aiming to change the entire landscape of modern communication. However, with the concept of communication between all communicable machines themselves, a problem of high energy requirement to match the massive data transfer handling due to dense channel access comes into the fray. Therefore, to devise a fully functioning tech as such it is very important to consider a proper design of an energy-efficient technique to

handle the vast data rate and dense channel access. Hence, we design a hybrid energy-efficient MAC protocol for M2M communications. This solution not only improves existing protocols but also takes the advantage of clustering in cellular networks to save energy and thus aims to improve the overall efficiency of M2M communication.

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BIOGRAPHIES

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