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An Enhanced Hybrid Medium Access Control Scheme for Machine to Machine Networks

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ABSTRACT: *A Strong medium access control (MAC) protocol is required for machine type devices to concurrently access the channel in Machine-to-Machine (M2M) communication. Simple MAC protocols may not be able to provide a scalable solution for M2M networks with large number of heterogeneous devices. A scalable hybrid MAC protocol, consisting of contention period and a transmission period, is designed for such M2M networks. In this protocol, different devices with preset priorities, first contend the transmission chances following the convention based p-persistent carrier sense multiple access (CSMA) mechanism. Successful devices only will be assigned a time slot for transmission following the reservation based time-division-multiple-access (TDMA) mechanism. If, the devices failed in contention in previous frame and to ensure the fairness among all devices, their priorities of contention will be raised by increasing their contending probabilities at the next frame.*

In this paper, enhancement in new protocol, is explained over the existing protocol by introducing slotted aloha before data transmission period. We evaluate our performance with Distributed Coordination Function (DCF), existing and the proposed scheme in terms of delay, throughput ,and goodput, and we see that proposed system is very efficient than the other two protocols.

Keywords: *Hybrid MAC Protocols (HMP), Internet of Things (IoT), Machine-to-Machine (M2M),*

I. INTRODUCTION

In this age of computing, remote connectivity without human involvement is the basic need for all industrial sectors, whether it, be retail, logistics or enterprises. In such a scenario, M2M network turns out to be much helpful solution. M2M represents a future IoT where more than trillions of everyday objects and the surrounding environment are associated and succeeded through a range of devices, communication networks, and cloud-based servers [1]. In many M2M communications applications, machines are expected to be low cost, so that they can be easily embedded in real fields and extensively deployed in a large scale [2].

The serious MAC layer challenge for M2M communications lies in smoothing channel access to extremely large number of devices while supporting the various service requirements and distinctive traffic characteristics of devices in M2M networks. Generally there are three classifications of MAC protocols viz. Contention based, Reservation based and Hybrid.

While Contention based and Contention free MAC protocols have many advantages like high gain at low network load, energy efficiency, good channel utility even at high load (for Contention free scheme), they are not able to scale when there are huge number of devices. Hybrids of these techniques can be and frequently are used and are suitable for vast M2M networks.

The main objective mentioned here is to provide a frame based hybrid-MAC scheme, consisting of a CSMA contention period and a TDMA transmission period and use best solution to the problem to adjust both periods in each and every frame in order to increase the utilization of channel. The aim of the present protocol is to divide total time period into number of slots equally allotted based on the number of directly connected links. TDMA scheduling is used to distinguish individual slot and rest of the slots are used to perform sleep in inactive devices.

Many MAC Layer protocol are studied in literature. Slotted Aloha is very simple protocol. Cellular communication system uses S-ALOHA random access to permit users to enter the system and contend for a traffic channel [3]. In slotted aloha, time is split into slots and each station sends the packet only at the starting of the time slot. Since each station is permitted to send only at the beginning of the synchronized [4] time slot, if a station fails to transmit, it should wait until the beginning of the next time slot. This means that the station which is in progress to transmit data in this slot has already finished sending its frame. But possibility of collision is not reduced as any station can randomly transmit data at beginning of same slot.

In order to overcome the drawback of Slotted Aloha, to minimize the probability of collision p-persistent CSMA was developed. Usage of p-persistent CSMA is exclusively for slotted channels and is sort of enhancement between 1-persistent and non-persistent CSMA protocols. Recently, the performance analysis of p-persistent CSMA protocols have gathered a renewed interest since the behavior of the IEEE 802.11 MAC protocol can be closely studied by a p-persistent CSMA model [5]. In order to avoid collisions, all stations utilize IEEE 802.11 DCF (four way handshaking) [6, 7] protocol, which employs carrier sensing technique before any data transfer. There are two types of carrier sensing mechanisms, viz. Physical Carrier Sensing (mandatory), and Virtual Carrier Sensing (optional).

In TDMA, the bandwidth of the channel is shared among stations in time. Each station is assigned a time slot in which it can send data. Every station transmits its data in its allotted time slot. In [8], the authors propose a novel TDMA-based MAC protocol to conserve energy and increase data transmission efficiency of sensors in a cluster-based WSN, and also in their scheme, nodes that have no data to send can go into sleep mode for energy conserving while on the other hands, nodes that have more data to send can ask the cluster head to allocate more time slots for data transmission. One of the drawbacks of TDMA is slot assignment failure [9]. The slot assignment failure [9] eventually leads to communication failure between the intelligent devices in M2M domain.

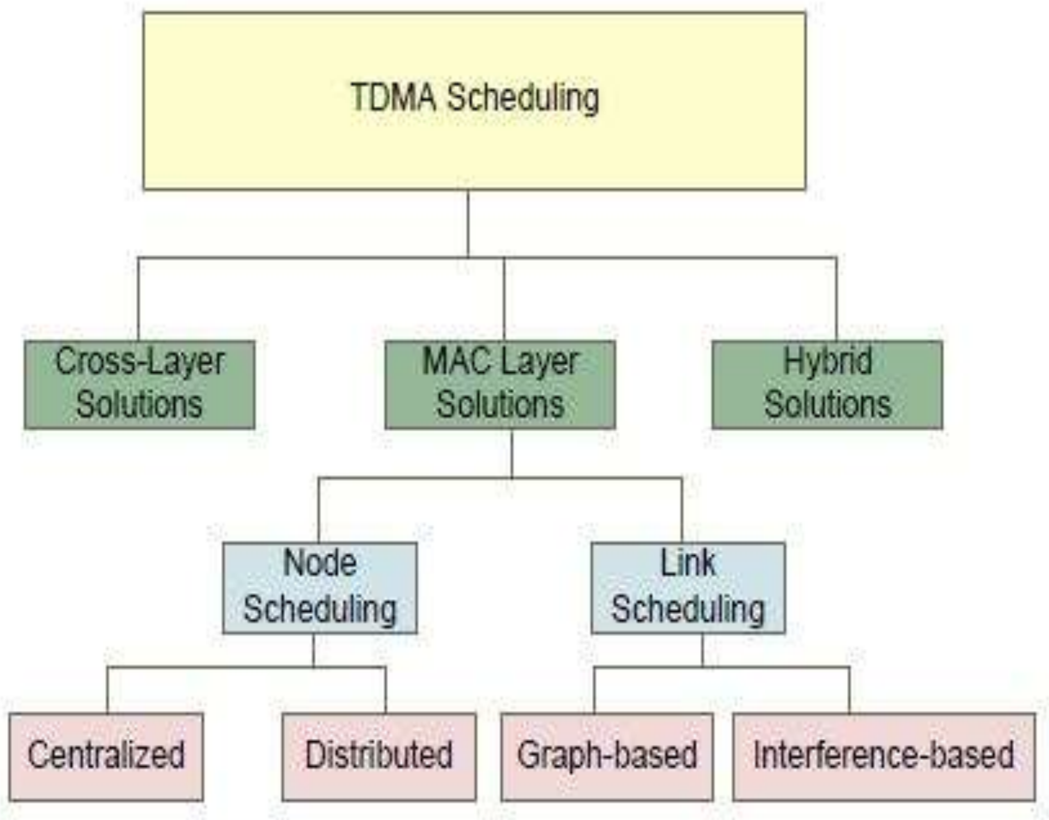

Figure 1: TDMA scheduling algorithms

There are various problems in wireless multi hop networks and one of the key problems is the scheduling of transmissions in a fair and effective manner. TDMA appears to be one of the principal solutions to achieve this goal, since it is a simple scheme and can extend the devices' lifetime. Several TDMA scheduling algorithms [10] are found in the literature which is shown in Fig. 1.

Many Hybrid Protocols are present in literature, starting with the Wireless Sensor Network (WSN), we have Z-MAC [13], it combines the strengths of TDMA and CSMA while offsetting their weaknesses and like CSMA, Z-MAC achieves high channel utilization and low latency under low contention and like TDMA, achieves high channel utilization under high contention and reduces collision among two-hop neighbors at a low cost.

In paper [1, 11], a hybrid protocols for large M2M networks is presented, which consists of four periods viz., Notification Period (NP), Contention Period (COP), Announcement Period (AP), and Transmission Period (TOP) and also to balance the tradeoff between the contention and transmission period in each frame, an optimization problem is formulated to maximize the system throughput by finding the optimal contending probability during contention period and optimal number of devices that can transmit during transmission period. An enhancement is carried out in [12] by integrating IEEE 802.11 DCF in each TDMA slot so that during TDMA clock synchronization failure, communication failure should not be compromised between intelligent M2M devices.

1. Proposed System model

The system model for the M2M Network is shown in Fig. 2. It consists of three domains as described below [14]:

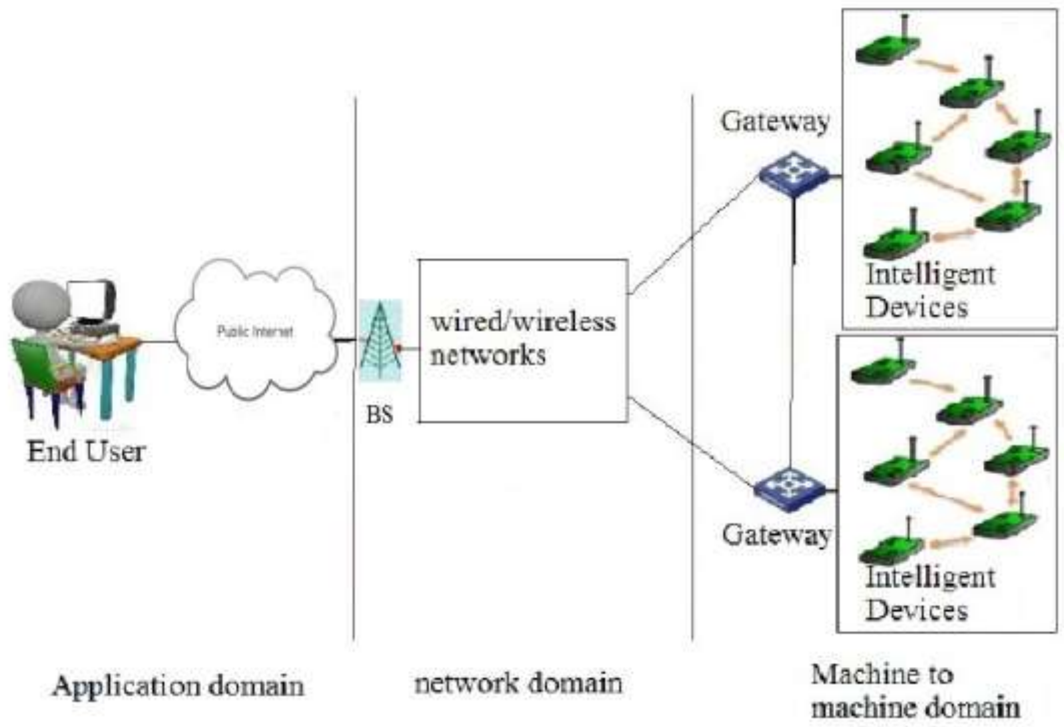

Figure 2: Proposed system model

2.1 M2M Domain

In the M2M domain, an M2M area network is theoretically formed by a large number of intelligent M2M devices {N0, N1, ...} and an M2M gateways (GW). Each M2M node Ni is a very flexible and smart device furnished with some specific sensing technology (for example, body sensors in an e-healthcare system or other types of sensors in environmental surveillance) for real-time screening. Once screening data are sensed, M2M nodes will make intelligent decision and transmit the sensory data packets to the GW in single-hop or multi hop patterns. The M2M GW is an integrated device. After collecting the packets from M2M nodes, it is able to intelligently manage the packets and provide efficient paths for forwarding these packets to the remote base station (BS) via wired/wireless networks.

2.2 Network Domain and Application Domain

In the network domain, the great accomplishment of wired networks and the ubiquity of wireless networks (e.g., 3G cellular, WiMAX, and municipal Wi-Fi) offer cost-effective and reliable channels for transmitting the sensory data packets from the M2M domain to the application domain via BS.

In the application domain, the public internet is the key component for the whole M2M communications paradigm, which forms the data assimilation point for storing all sensory data from the M2M domain, and provides these real-time data to a variety of M2M applications or end users.

2.3 Proposed Work

M2M Hierarchical network is deployed which consists of internet, GW, BS, devices and sensors. Basic IoT setup is executed in the network layer to establish M2M communication. We Assume Heterogeneous scenario [1] in our simulation, where contending priority will be raised for each device after unsuccessful contention attempt for fairness of M2M devices in each frame.

At the beginning of frame, BS broadcast notification message to all devices in the network to identify number of devices to contend the data slot. Devices receives the notification message and check for the data to transmit, If it has data then prepare_to_contend the slot, Otherwise goes to sleep state. During this notification, BS identifies the packet arrival rate of each active device and estimates the optimal contending parameter such as contention probability, duration and incremental indicator. These information's are included in the notification message and receiver devices, estimates its own contending probability. The devices which are not participating, the data transmission go to the sleep state to save the energy.

The devices which are prepare_to_contend the slot performs the contention process using the (persistent_prob) and based on their own contention prob estimated in notification period. These devices send the transmission request to the BS. The device completes the successful contention when it sends the Tran-REQ. If more devices the, contends the same slot then collision prob is estimated. BS receives this Tran-REQ message, BS starts ack timer to compute the optimal contention period and to send the ACK Message. Device receives the ACK Message and stop sending the Req message and waits for the AP frame, Here ACK Message contains the slot index and time period of slot required for the data communication. The total slot is divided equally for all devices using TDMA setup to be used in TOP.

BS initiate the announcement messages to all devices, devices receives this announcement and checks for the successful contention, will start sending own data in TOP. Remaining nodes go to the sleep state.
The devices which are ready to transmit the data, it switches the state to transmission mode, wake up from the sleep state. It checks the allocated TDMA slot for the own by the BS, It validates the packet duration which need to be completed in the current slot itself. If it is not fit in the slot, it performs the transmission need to be filled in this slot, else moves to the next frame to transmit the data.

The slotted aloha is implemented before during the data transmission, Total time period is divided into number of slot equally distributed based on the number of directly connected links. The individual slot is identified based on TDMA scheduling and the remaining slots are used to perform the sleep in the inactive devices.

II. RESULTS AND DISCUSSIONS

Table I: Simulation Parameters

Tframe	100ms	Frame Period
Initial Energy	100J	Initial Energy of each node
rxPower	0.01W	Receiving Power of the device
txPower	0.02W	Transmitting Power of the device
Packet Size	2000 bytes	Packet Size
Data rate	3 Mbps	Data transfer rate
Slot duration	100 ms	Duration of slots for data transmission
CSThresh_ RXThresh_	250 m	Range

We compare our proposed protocol with the DCF [7] of IEEE 802.11 and existing hybrid mac protocol scheme [1, 11] in terms of delay, throughput, goodput, and channel utilization. We set the probability 'persistence_prob' to be 0.8 for DCF and for both existing protocol and proposed protocol to be 0.9 and in all three schemes incremental indicator α is 0.01. The environment that we use is ns 2.32 for simulation purpose. The simulation parameters are as shown in Table 1.

3.1 Delay

A comparison between delay of DCF protocol of IEEE 802.11, existing hybrid-MAC protocol and proposed hybrid-MAC protocol is made. Delay is an important design and performance characteristic of a computer network or telecommunications network. The delay of a network identifies how long it takes for a bit of data to travel across the network from one node or endpoint to another. It is characteristically measured in multiples or fractions of seconds. Here, we define delay as ratio of transmission time of each packet to number of successful transmissions of the M2M device during simulation.

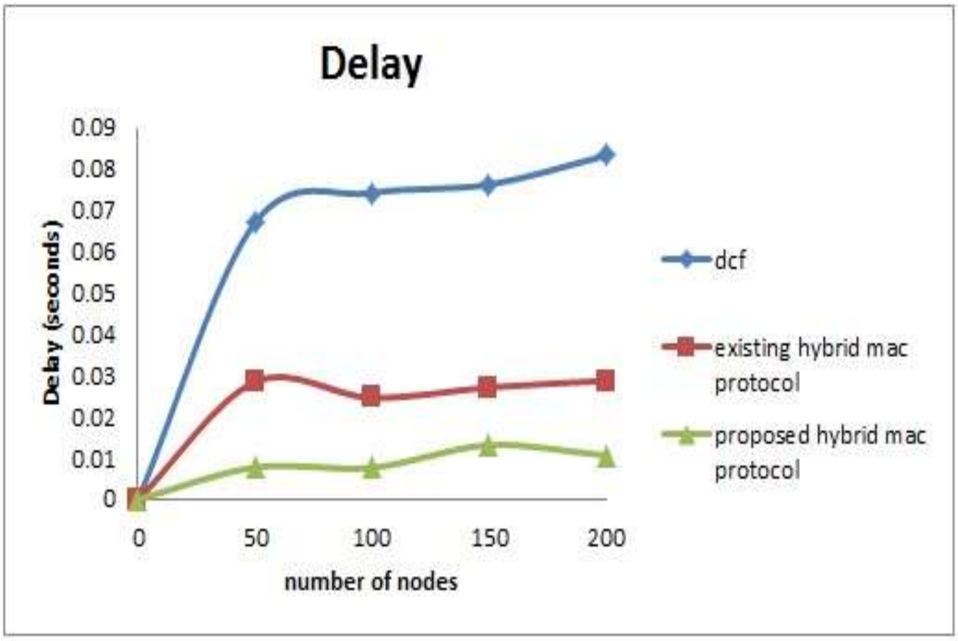

Figure 3: number of nodes vs. delay (in seconds) for all three schemes

We can observe that the delay increases as the number of devices increases. This is because the growing number of devices can cause the increasing collisions at COP of a frame, which leads to the increasing transmission delay however from Fig. 3, that proposed protocol achieves lower delay than that of the other two because in proposed system, total time period is divided into number of slot equally distributed based on the number of directly connected links.

3.2 Throughput

Throughput can be defined as the rate of successful message delivery over a communication channel. This data may be sent over a physical or logical link, or pass through a certain network node. Here, a comparison of throughput is made in terms of the total number of nodes between dcf protocol, existing hybrid-MAC protocol and proposed hybrid-MAC protocol. Throughput is measured in bits per second.

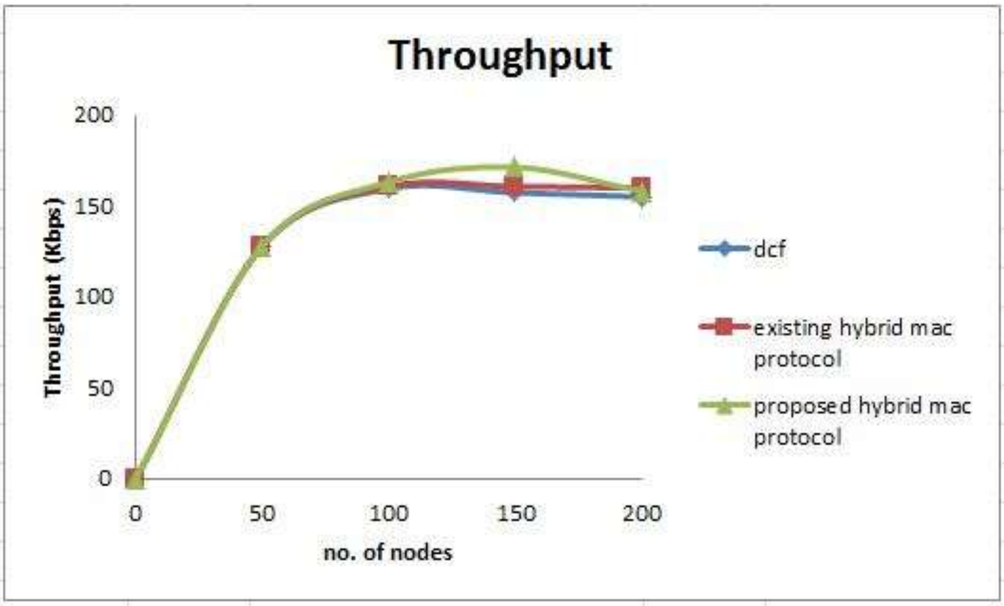

Figure 4: number of nodes vs. Throughput (in kbps)

From Fig. 4, it is observed that the proposed hybrid protocol is able to increase the probability of the contending devices when it continually failed in the contention in previous frames. Because of this mechanism it is guaranteed that all devices have fair chance to obtain the transmission slot, which leads to high network throughput.

3.3 Goodput

In networking, goodput is the application-level throughput i.e. the number of useful information bits delivered by the network to a particular destination per unit of time. We compare our proposed protocol with dcf and existing schemes. We see from above figure that goodput of the proposed system remains high with respect to the other two protocols. Here, goodput of the system is given as ratio of no of bits received to transmission time of each packet.

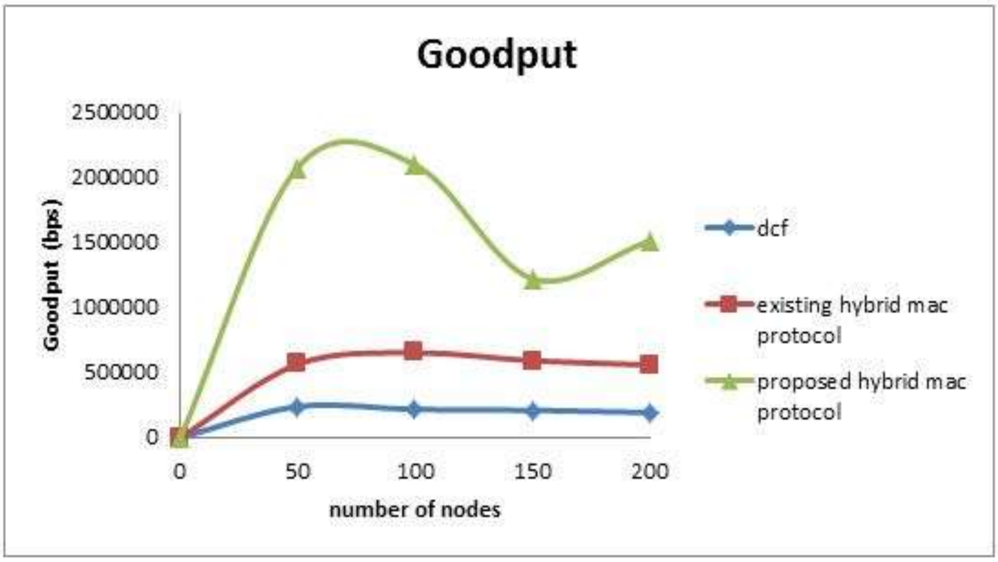

Figure 5: number of nodes vs. Goodput (bps)

It is observed from Fig. 5, that proposed protocol achieves good results for goodput than that of the other two because in proposed system, total time period is divided into number of slot equally distributed based on the number of directly connected links. Due to the use of slotted aloha before data transmission, a random access mechanism, goodput increases at first and then decreases gradually as number of nodes increases.

III. CONCLUSION

In this project, we have designed the hybrid MAC protocol for large heterogeneous M2M network where the intelligent devices have dissimilar service requirements. In our protocol, the frame at mac layer is divided into four period viz., NP, COP, AP, and TOP.

The proposed approach has SATDMA concept. This algorithm has been designed and implemented to handle together the QoS requirement and the slot synchronization failure in the HMP.

The dissimilar devices with different contending probability contend the transmission time slots during COP and successful devices only in contention will be allotted the time slots for transmission. Considering the fairness, the contending probability of the device that was unsuccessful in contention at previous frame will be increased at the next frame. Under such mechanism, the Base Station can easily maximize the channel utilization by controlling the duration of COP, initial contending probability 'persistence_prob', and the incremental indicator α. We have analyzed the delay, throughput, and goodput to show the effectiveness of the proposed hybrid MAC protocol; especially, when there are dissimilar devices with altered priorities.

The major area of immediate research is the extension of the proposed HMP which can handle intelligently, the M2M on different evaluation parameters like delay, goodput, and throughput. Future work may include testing the performance of our protocol for various HMP applications with several topologies and varying number of nodes and TDMA scheduling algorithms.

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