ITDMA-MAC: An Efficient TDMA-Based MAC Protocol for Dense Networks

Xiaoguang Zhu
Dept. of Electronic Engineering
Shanghai Jiao Tong University, Shanghai, China

Abstract: Medium access control (MAC) protocols for special environment is always hot. In this paper, I design a new kind of MAC protocol based on TDMA, called ITDMA, to satisfy a special situation, dense-network, in which there is only one AP with lots of stations and protocol based on CSMA/CA cannot work well. Stations in ITDMA can decide the time to sleep and wake up automatically with the information-exchange with AP. And time in ITDMA is divided into several part, called phase, and different phase have different function as well as different length. It's these phases' function that make ITDMA works. Stations in ITDMA use a counter-based method to keep synchronization with AP during the work. As a result, the characters of ITDMA are dynamical length, energy saving, counter-based synchronization and so on. Thorough the mathematical analysis and the simulations in MATLAB, I find ITDMA can work well in dense-network, and its time efficiency is extremely high. But there are some flaws, too, such as long access time, which need I to improve in future work.

I. INTRODUCTION

Media Access Control, abbreviated as MAC, provides addressing and channel access control mechanisms that make it possible for several terminals to communicate within a multiple access network that incorporates a shared medium. Nowadays, wireless-communication has been widely used in our daily life. When we access the WIFI, we use MAC to control wireless connection; when we use GPS, we use MAC to control wireless connection; even when we want to machine to communicate with each other, we also use MAC to control the connection interface. So it is important to design a wonderful MAC protocol to fit the different function in different scene.

As a result, IEEE has standardized the 802.11 protocol for Wireless Local Area Networks [1]. The primary Medium Access Control (MAC) technique of 802.11 is called Distributed Coordination Function (DCF). DCF is a Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) scheme with binary slotted exponential backoff. Carrier sense means that a transmitter uses feedback from a receiver to determine whether another transmission is in progress before initiating a transmission.

But when DCF is designed, at about 1999, the total number of stations is only about ten at most. Since our network become more and more dense, the weakness of DCF become more and more obvious:

- As the amount of stations increases, the occurrence of collision become more frequent. Collision occurs when two station want to send message at same frequency and same time. Although the technique of handshaking can be used to decreased the harm of collision, it still be a big waste of bandwidth.

- The access point cannot manage the total number of stations, since the join of station is decided by the station itself, rather than access point. So when the total number of station is huge, it cannot control this situation and can only let it impair the performance of network.

- Besides, the idle listening and overhearing, two of the most significant causes of unnecessary energy consumption in wireless sensor networks, become more severe in dense-networks. Idle listening refers to a node listening to a wireless channel when there is nothing on the channel to receive, and overhearing refers to a node hearing packets not intended for this node.

On the contrary, the concept of TDMA can solve these problem easily, since there is no collision will happen here and node can wake up itself without hearing the channel. TDMA is abbreviation of Time Divided Multiple Access. It is an other channel access method for shared medium networks. It divide the whole time into different time slots so that the users can transmit one after the other, each using its own time slot.

TDMA need managing the transmission array, and if amount of node who want to transmit data fluctuates, the organization can be very difficult. We have several TDMA protocol yet, but there are some shortcomings of traditional TDMA-based MAC protocol:

- Most of extant TDMA's frame length is fixed, due to which the packet transmission delay will increase in proportion to increasing frame length.

- The channel is under-utilized when traffic demand is low and lots of time slot is wasted.

- When traffic demand is high, there is only fixed amount of allocated bandwidth (or limited number of TDMA slots) that cannot afford unlimited stations.

So the old TDMA protocol cannot be applied to dense-network directly, and we need to improve and complete it in detail. As a result, I come up with my own MAC protocol, ITDMA-MAC protocol, to overcome these disadvantages and make it perform better in dense network.

Section 2 of this paper discusses related work. In Section 3, I present the design of ITMDA-MAC, including some analysis of criteria. Section 4 presents the results of simulation of ITDMA-MAC using MATLAB under different situation. Finally, in Section 5, I present the conclusion and the future work.

II. RELATED WORK

Many MAC protocols have been proposed for different situation, and most them use only a signal radio channel for all transmissions; examples include Hybrid-CSMA/CA-TDMA-MAC[2], SA-MAC[3], EM-MAC[4] and so on.

Hybrid-CSMA-TDMA-MAC, just as its name, is a MAC protocol that using both CSMA/CA and TDMA technology. The designer thought that CSMA/CA could be used by the wireless nodes to send the channel access request in a hybrid CSMA/CA-TDMA-based wireless network. It use superframe as their basic unit, and each superframe have many slots that can be classified either CSMA/CA slot or TDMA slot. Wireless nodes synchronize their superframes with the coordinator by the help of a beacon frame. The whole length of superframe is inactivity, equal to the sum of CSMA/CA slots, TDMA slots, and beacon slots. It are useful in realizing low-power and low-rate wireless networks, but it is incompatible with our goal in dense-network.

SA-MAC (Synchronous after Awake MAC) is a MAC protocol for wireless sensor network (WSN) . Its main approach for reducing the waste of energy due to idle listening is to lower the radio duty cycle by turning the radio on and off. Nodes wake up periodically to participate in potential network communication, and build a logical tree to determine which to send. It is a multi-hop as well as an energy-saving protocol. It still be, however, time-consuming, which is forgivable in WSN but not in dense-network.

EM-MAC also be a protocol for WSN, but it introduces of novel mechanisms for adaptive receiver-initiated multichannel rendezvous and predictive wake-up scheduling, which is an excellent example for us to learn. Each time a node using EM-MAC wakes up, it independently selects its own wake-up time and channel according to a pseudorandom function. Each time send node and receive node communicate with each other, they transfer the parameter of pseudorandom function, which can spread the traffic load to different channels and avoid the jammed channel. Using these mechanism can save energy as well as decrease the channel collision.

To our knowledge, forwarding research on MAC protocol focus on the WSN and pay more attention on energy saving. But it still useful since these method, such as hybrid method and predictive method, can also be used in our protocol to help me improve my protocol's performance. Besides, I will focus on the improvement of throughput and will take care of energy saving meanwhile, both of which are essential in dense-network.

III. ITDMA MAC PROTOCOL DESIGN

The letter "I" in ITDMA means "Information-exchange". It indicated that there are lots of information-exchange in my protocol, which can entitle the receive node in my protocol to forecasting the transmission time and then turning asleep and waking up automatically. But the information-exchange won't happen all the time, since I classify the time in my protocol into different phase, and each of which have certain function. These will be introduced in this chapter.

First of all, I'd like to make a assumption. Since ITMDA focus on the situation of dense-network, for example the WIFI network with lots of mobile stations, there must be an access point (AP) to manage the whole connection. Others are nodes, called stations, to get into connection with access point. And my work aims to arrange one AP and lots of stations in limited frequency channels and make made them work well.

A. Hierarchy of ITDMA

Before my introduction the time-hierarchy of ITDMA, I'd like to inform you of the basic idea of my protocol.

The AP and station following my protocol are demand to do right thing in right time slots. AP has a transmission array (TA) that store the whole stations that will connect with it, as well as the whole-id packet (WP) that store the identification of stations that ever joined it recently. Each time AP ask for the join of new stations, AP will listen their reply in a dynamic amount of time, in which stations will announce their existence in the certain location based on Hash Equation (HE). Then AP will talk stations that the order of transmission later in a dynamic way, which won't talk so much time. Finally, transmission begin between them.

Knowing this basic idea, Let's get understand of time-hierarchy now. There are three time units in my protocol, $period$, $phase$, and $slots$. Period is the biggest one, and every stations use the certain slots of each period to communicate with AP. And the amount of stations is uncertain so the length of period is dynamic. Each period is divided into different phase, each of which charge one certain function and consist of several slots. Just as period, different phase have different length. And time slot is the smallest unit in ITDMA.

Figure 1 illustrates the relationship of period, phase, and slot in ITDMA. There are four phase every period at most, and following statement will talk about phase mainly.

B. Procedure of ITDMA

Phase is the functional unit in ITDMA, so I will introduce the procedure of this protocol by introducing the function of

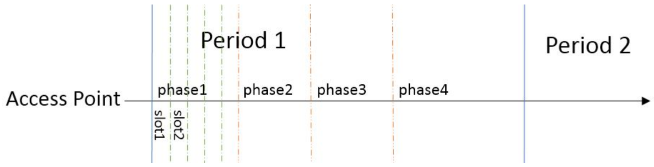

Fig. 1. Relationship of period, phase and slot

each phase.

Assuming that the protocol has been running for some time so there are several stations already in TA and will continue communicating with AP in the following period. With any declaring, these station will keep the tacit location of communication with AP in phase four, Transmission-phase. The first three phase is prepared for new-join stations as well as for synchronization, but its length is much shorter phase four.

The first phase is called Broadcast-phase, in which AP broadcasts information of itself, such as the id and length of TA and so on, and the length of Hash Equation(HE) this period. The length of HE should be decided by the new coming stations this period, and since the new coming stations cannot be known by AP, AP can decide it by the coming stations of last period. We assuming that the new coming stations this period is just as much as last period, so we can adjust the length of HE dynamically. I rule that if the occupied bits in HE is more than 1/2, or there are more than 1/4 amount of bits declared, AP should double the length of HE; otherwise, the length of HE can remained in a low level.

In addition, though this phase, AP can also control the total number in TA. If AP want to guarantee a good performance of current station's transmission, it can monitor the length of TA, and once the length of TA reach a high level, it can declare in phase one that it won't let new station in unless some stations is out. In following statement, this special situation won't be considered unless there re special illustrations.

Base on the length of HE that broadcast in phase one, the length of phase two, Declare-phase, is known by all the stations. Then, if a station that isn't in the TA currently want to join TA this time, it will calculate its location of time based on the its id as well as HE. Then it will declare its existence at the certain time slot of phase two. For example, if the length of HE is four, and Station-A got the number six, and it will declare its existence in the second time slot because six mod four equal to two. Figure 2 shows an example of this phase.

Then comes in phase three, Manage-phase. After AP getting the information of all new-join stations, it will inform new-join stations the time to transmission in phase four, by sending them a series of bit-code-series as well as the amount of already-in stations (the length of TA if not body new in). The bit-code-series is consist of eight times length of HE, and each eight bits are called a frame. The location of each frame represents the number of HE-bit. For example, the fist frame, the first eight bits in bit-code-series, is the information of first time slot in Declare-phase, the first bit in HE. The first bit of each frame indicate the existence of stations that declare in that bit. If the first bit of frame is set, it means that there are some station declare their existence in that bit; otherwise, there is no stations declares. If this bit is set, the other bit represent the number of stations that maybe declare at the same time. Since AP cannot recognize the number of collision signals, it can only speculate the number of stations using the stations' information in WP.

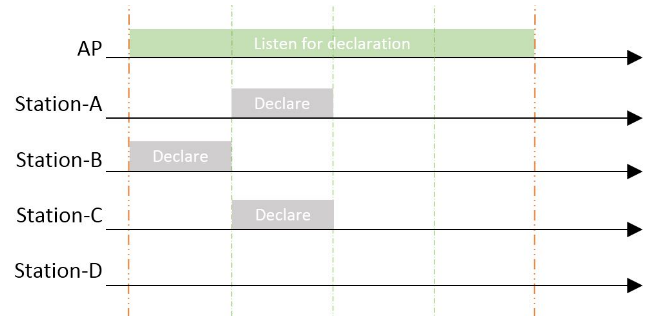

Fig. 2. Example of Declare-phase : Assuming that the length of HE is four; Station-A want to join TA and get number six; Station-B want to join TA and get number 3; Station-C want to join TA and get number 2; Station-D do not want to join TA this time or it already be in the TA

The structure of frame is showed in Figure 3. So if there are three station in whole-id packet that may declare their existence in bit two, the AP of the example showed in Figure 2 will generate the bit-cod-series like 10000001 10000011 00000000 00000000.

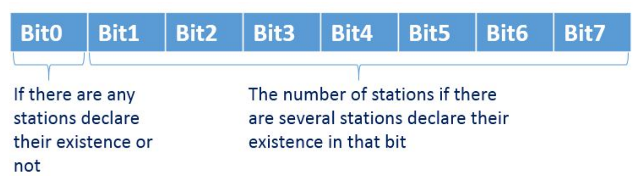

Fig. 3. Structure of Frame in Manage-phase

Finally, the transmission will begin in phase four, Transmission-phase. The old stations in TA transmit firstly, and they will keep their location of transmission unchanged and each of them will take a length of time called frame-M. Then, the new-join stations will come to communicate with AP. As they know the result of phase two in phase three as well as the bit they send in phase two, they will know the location of their transmission in array. For example, Station-A will know that there are only one station before it, and in its location there are at about three stations (3 times of frame-M). Then they will use CSMA/CA as a method to join in that length of time just as showed in Figure 4. Although there will be some station left, most of them will join the station successfully. More information about CSMA/CA can be found in [1].

Besides, in case the AP made an erroneous judgement that there is no stations or only one stations in some bit, one station can keep awake for a while after its transmission. If

AP find that itself made an erroneous judgement, it can ask the former station to carry on transmission to get a better time efficiency. That is the basic function of each phase and the basic procedure of ITDMA. As you can see, there will be free of collision except the CSMA/CA part. And there are some supplement that I will talk in the following chapter.

C. Info. exchange

As the letter “I” in ITDMA means “Information-exchange”, I will conclude the information-exchange process in ITDMA in this chapter.

There are information-exchange happened in Broadcast-phase, Declare-phase, Manage-phase as well as transmission phase. And the first three information-exchange have been instructed in former chapter.

Information-exchange in Broadcast-phase is that AP will broad its own information as well as the length of HE.

Information-exchange in Declare-phase is that the new-join stations inform AP of their declaration to join of TA. No matter how many stations want to join in that period, the length of Declare-phase has been decided in Broadcast-phase. And unlimited number of stations will use limited length of time to declare their declaration through the collision-utilization-method (CUM). CUM assume that AP can certain code even a collision happened. Just like our talking, one person cannot hear anybody if they talking about different things, but will understand they signal if they all send the same one. So the potent new-join stations will send same signal, same signal except a small different decided by its id, in the certain slot of Declare-phase decide by the HE and its own id. As a result, if AP receive that certain signal in one slot, it will consider this bit of HE is been taken. If AP senses that there are more than one station sent signal in same bit by sensing the different part of signal, it will go to its whole-id packet to find the maximum possibility of station that may join AP this time.

Information-exchange in Manage-phase is that AP broadcast the new length of TA, which equal to the length of current TA plus the possible amount of new-join stations, and the result of phase two to stations. AP broadcast the length of new length of TA first, and all the stations need this information since they should know that length of Transmission-phase, which equal to length of new TA times length of frame-M, to locate the head of next period. After that, the new-join stations will receive the information of Declare-phase concluded by AP through bit-code-series. Then the already station will keep the location of themselves in Transmission-phase, and the new-join station will calculate it by analyse the bit-code-series.

Finally, information-exchange also happen in Transmission-phase. It is also the method for station to quit the TA. When a station finish its transmission and decided quit next time, the stations whose location in TA is after that station should move one bit forward. This protocol make this change implemented flexibly by adding some information in transmitted packet. First of all, the wanna-quit stations will inform AP of its quit as soon as its final transmission. After its quit, AP will inform to latter station of the change in TA by adding number of quit-stations while communicating. As a result, the latter station will get the information of change, and will change their location automatically, which waste little time to adjust them.

That all of information-exchange in this protocol. As we can see, the whole protocol is based on the information-exchange and that method help protocol save lots of time. That why I call this protocol ITDMA.

D. Energy Saving

During my introduction of ITDMA, you may have recognize that not all the information is essential for all stations in my protocol. As a result, the stations also have the duty circle, and since energy consumption is related closely with duty circle, my protocol can also reach the result of energy saving.

As the example showed in Figure 5, stations can go to sleep while they have nothing to do with AP.

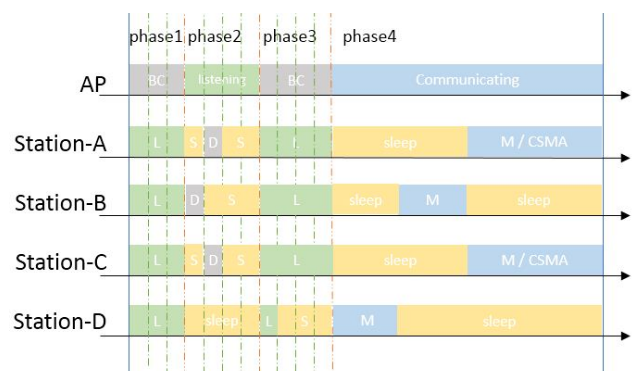

Fig. 5. Example of duty circle: L means listening; S means Sleeping; D means declaring; M means communicating; BC means broadcasting.

In Broadcast-phase, all the stations that already in the TA or want to join the TA should listen broadcast of AP, because AP will send the information that they need in following phase.

In Declare-phase, stations that already in the TA can fall asleep to save energy, and the new-join can only wake up in the certain slot to declare its existence. But the AP should always been awake to receive the signal from stations.

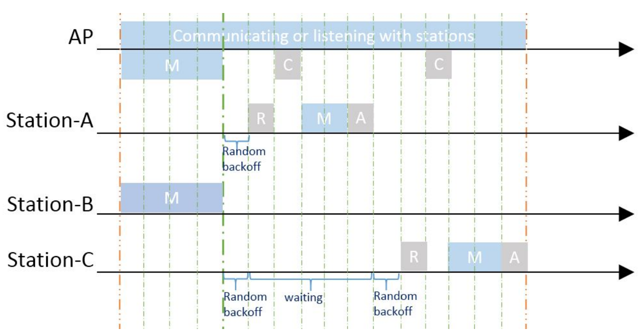

Fig. 4. Example of Transmission-phase : Assuming transmission of ready-in stations in TA is over, and station-A and station-C will use CSMA/CA to join the station (this is only a simply hint of CSMA/CA, since there are also DIFS as well as FIFS in CSMA/CA). R means RTS; C means CTS; M means communication.

In Manage-phase, all the stations that already in the TA or want to join the TA should listen in first slot to know the length of transmission. After that, the already-in stations can fall asleep to save energy since the length of phase three can be decided by length of Declare-phase (both the length of Declare-phase and the length of bit-code-series is decided by length of HE). Then they can calculate out the head of Transmission-phase as well as the communication-location of themselves. Then in transmission, all the station can only wake up at certain time to communicate with AP.

With the duty circle in this protocol, all the station can save lots of energy without lowing the performance. As for AP, since we talking about dense-network, more time AP working validly, more efficient this protocol is. So unless the current TA is zero meanwhile no new-join stations, AP should not rest.

E. Synchronization

As a protocol based on TDMA, it must be a method to keep synchronization.

In my design, I assuming that both the AP and stations have the wonderful internal clock that only need to be calibrated sometimes. Besides, we cannot calibrated one clock without the standard one. So it is important to find the standard clock in ITDMA, and clock in AP is the perfect choice since AP is the only one who never sleep during the work time. So the clock in AP is remain stable, and only the clocks in stations need adjusting.

This protocol use clock to count down a number, called count-number, to represent the length of each slot, and the clock itself works as a counter. So what we should do in synchronization is to adjust the count-number. It can only be done when the stations will receive the clock information from AP. As we can see in Figure 5, there is only two time slot that all the working station is awake, that is phase one and the first part of slot in phase three. So we can use one slot in phase one, called standard clock slot, to synchronize the clock in station with one in AP.

First of all, every station will as a default value of count-number, whose theoretical length is equal to one slot. Then, every time that station knows the standard clock slot is coming, stations will be awake a little earlier, and prepare to catch the head of standard clock slot's head. After catching it, station will compare it with a short time interval, called tolerance interval, can decided whether the count-number is bigger than the real one, or smaller, or precise enough. Though the compare between the head of standard clock slot and tolerant interval, station reach the result of synchronization.

The process of synchronization is shown in Figure 6.

In addition, even a station is already synchronized with AP, it also need to wake up a little early for security.

IV. Analysis and Simulation

After the introduction of ITDMA, it is essential for us to analysis this protocol mathematically. There are several indicators that can react one protocol good or not: throughput(also

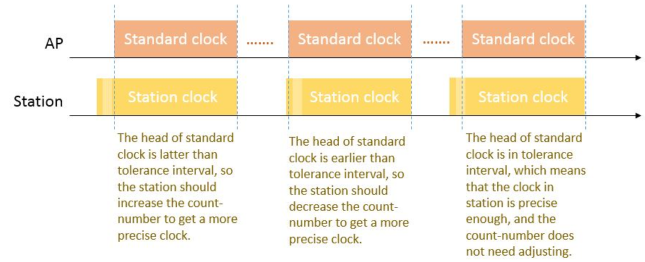

Fig. 6. Example of adjustment of clock in station

referenced as time efficiency), energy consumption, access time, ans so on. Both of them can be analyzed in math as well as simulated in professional tools.

In this section, I talk about the time efficiency of ITDMA mainly. Other criteria like energy efficiency can be related with more realistic factors that is hard to analyze and simulate.

A. Analysis in Mathematics

As we know, the length of whole i^{th} period T_{ai} equals to the sum of length of phase one to phase four.

$$T_{ai} = \sum_{j=1}^{4} T_{pj,i}$$

And valid time, means time used to transmission rather than management, of Period i^{th} is

$$T_{vi} = T_{p4,i} \times \mu$$

Where μ is the use rate of Transmission-phase. μ can be influenced by the order of new-joining stations, the length of stations' transmission, as well as the length of frame-M.
So the time efficiency of ITDMA is

$$\eta = \mathbb{E}[\frac{T_{vi}}{T_{ai}}] = \mathbb{E}[\frac{T_{p4,i} \times \mu}{\sum_{j=1}^{4} T_{pj,i}}] = \mathbb{E}[\frac{T_{p4,i} \times \mu}{T_a^1 + T_{p4,i}}]$$

Since the function of phase one is broadcast its own information, which is of certain length, so the T_{p1} can be set to a constant.

The length of both of phase two and phase three is decided by length of HE, whose length is declared in phase one, decided by the new coming stations last period. Assuming the expectation of new coming stations is N_a each period, and N_a is constant, so the length of phase two and phase three can be constant. As a result, $T_a^1 \approx C$, where $C = Constant$. As for phase four, its length equal to

$$T_{p4,i} = N_{ai} \times T_M$$

Where N_{ai} is the amount of stations in TA in i^{th} period, T_M is the length of frame-M, which can be decided by me. Then we have

$$N_{ai} = N_{a(i-X)} + N_{xi} - N_{qi}$$

Where N_{xi} means the new-join station in i^{th} period, and N_{qi} means the quitting stations in i^{th} period.

After the former discussion, the time efficiency can be rewrote as

$$\eta \approx \mathbb{E}[\frac{N_{ai} \times T_M \times \mu}{C + N_{ai} \times T_M}]$$

So what I should do is to choose a proper T_M that can lead to the maximum of η.

As described in [5], I consider the batch Poisson process as the station arrival model. In this model, a batch, which contains one or more stations, arrives according to the Poisson process. The arrival time and the number of stations of the j^{th} batch are described by X_j and Yj. For AP, the inter arrival time between batches, $X_{j+1}X_j$, is exponentially distributed with mean $\frac{1}{\lambda}$. The number of packets in each batch, Y_j, is identically and independently distributed. The probability mass function (pmf) of Y_j is denoted by f^Y.

I define A_τ as the number of arrived stations at AP during a time interval the length of which is τ. So $N_{xi} = A_{T_{ai}}$.

Since the packet arrivals follow a batch Poisson process, A_τ follows a compound Poisson distribution [6]. Therefore, the characteristic function of A_τ is given as

$$\varphi_\tau^A(z) = \mathbb{E}[exp(izA_\tau)] = exp\{\lambda_\tau(\varphi^Y(z){-}1)\}$$

where $\varphi^Y(z)$ is the characteristic function of Y_j such that $\varphi^Y(z) = \mathbb{E}[exp(izY,\tau)] = \sum exp(izy)f^Y(y)$. The pmf of A_τ, as well as N_{xi}, denoted by f_τ^A, can be derived from φ_τ^A, by means of the inverse formula for the characteristic function.

As for μ, it is influenced by lots of factors, too. According to the time efficiency of CSMA/CA in [1], the time efficiency of new-join station is about 67%. Although the CSMA/CA in this phase is different from the situation in [1], it still can be a reference. Since I have no other method, I assume the time wasting in CSMA/CA is about $N_{xi} \times T_M \times 67\%$. The time wasting in wanna-quit stations is about $T_{x(i-X)} \times T_M \times 50\%$, where $T_{x(i-X)}$ is the new-join stations of $(i-X)^th$ periods, and 50% means that the expectation of time wasting is about a half of frame-M. Finally, the time efficiency of ITDMA is

$$\eta \approx \mathbb{E}[\frac{N_{ai} \times T_M {-} T_{x(i-X)} \times T_M \times 50\% {-} N_{xi} \times T_M \times 67\%}{C + N_{ai} \times T_M}]$$

Where N_{xi} is decided by $A_{T_{ai}}$, and N_{ai} is decided by N_{xi} N_{ai} of former period and N_{xi}. And if we want to gain a high η, the only thing I can do is to choose a proper T_M.

As for access delay of ITDMA, T_d, I assumes that the coming of stations in every period is follow the hypodispersion. AS a result, the average access delay is

$$T_d \approx \mathbb{E}[T_{ai}] \times 50\%$$

Where the T_{ai} follows a compound Poisson distribution, so the access delay following a compound Poisson distribution, too.

B. Simulation in Matlab

Since the calculation of η is hard to calculate out explicitly, it's a good choice to simulate ITDMA in some professional tools. I use Matlab as a tool to simulate the η as well as T_d.

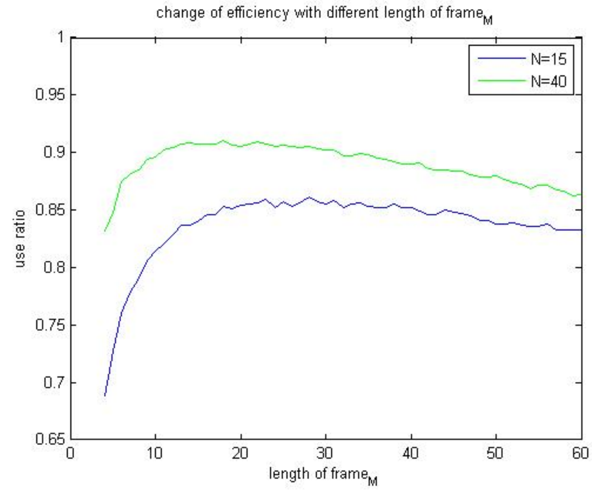

Fig. 7. Simulation of time efficiency under the variation of T_M: N means the total stations that join in AP, and one station join twice is considered as two stations.

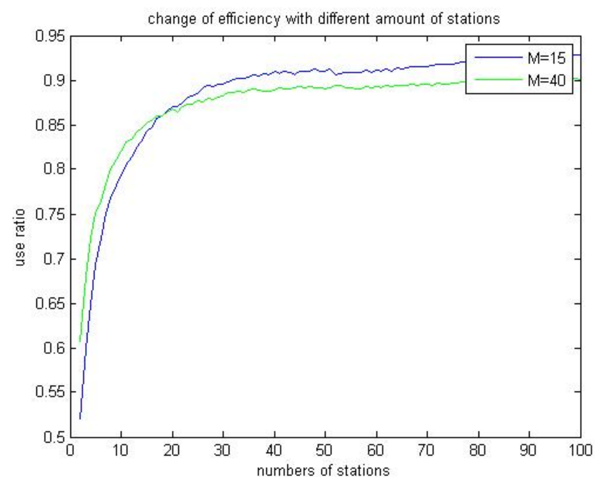

Fig. 8. Simulation of time efficiency under the variation of N_A

Just as before, I consider the batch Poisson process as the station arrival model, and the demanding time of each station follows the hypodispersion. Besides, I use the time slots as the units, and set T_{p1}, to 1 for convenience.

First of all, I simulate the value of η under the variation of T_M from 5 slots to 60 slots. The average result of 100 times simulations is shown in Figure 7.

As we can see, the relationship between T_M and η is close but not always positive, and if we choose the T_M from 15 to 20, we can get the η which is higher than 80%, which is far more better than 67% of CSMA/CA.

And how does the variation of amount of station influence η? Then I did the simulation of time efficiency under the variation of N_{ai}, which is represented by the change of total stations that join in AP, N_A. The average result of 100 times simulations is shown in Figure 8.

We get the answer that the relationship between N_A and

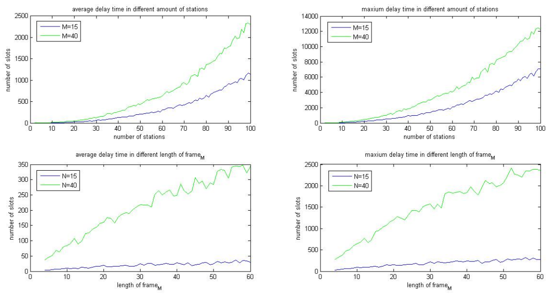

Fig. 9. Simulation of access delay: M means the length of frame-M.

η is always positive, which means that this protocol is fit for dense -network.

But as my former statement, the access delay maybe long since the period in dense-network is long. I did the simulation and the answer is shown in Figure 9.

In Figure 9, the picture in top left is average delay time under the variation of amount of stations, the picture in top right is maximum delay time under the variation of amount of stations, the picture in bottom left is average delay time under the variation of length of frame-M, and the picture in bottom right is average delay time under the variation of length of frame-M. I put four picture together for a better comparison between the average access delay and maximum access delay, the influence of T_M on delay and the influence of N_A on delay.

The results tell us that the access delay is of positive relation with both of T_M and N_A. And it can be really big if the network is dense meanwhile the length of frame-M is inappropriate. If we choose a good length of frame-M such as 15 slots, and access delay can be as much as 6000 slots when the total number of stations is about 100, which may take about 6 seconds in real life. Although that is not very long for most circumstance, since the access time of CSMA is pretty long, it still be a bad news. To assuage this problem, I come up with two method.

- As I said in chapter 3.2 , the AP can limited the maximum length of TA. With limited amount of stations, the access delay can be limited in a low level.

- ITDMA allow stations to join AP in other method instead of declaring in phase two. They can ask for the location of wanna-quit stations in phase four while it senses the quitting declaration of one station. And they should follow the rule of CSMA/CA because other station may also ask for joining the TA meanwhile.

V. CONCLUSION AND FUTURE WORK

A. Contribution of MYWORK

I devoted lot of time to my work, and I think that what I did dose have some contribution for real world.

- I come up with the utilization of collision, which nobody ever put forward before, and I think it can be used in other field, too.

- I come up with a MAC protocol that can be used in certain situation, and perform better than the extant protocol in some crteria like time efficiency.

- I change the traditional TDMA into dynamic one, which is a plausible adjustment for TDMA.

B. Flaws of MYWORK

This is the first time that I take so much time to learn and research something by myself, and there are some flaws in my work that need to be recover in the future work.

- I did not simulate CSMA/CA but used the conclusion of other paper, which is of low persuasion.

- I use MATLAB as tool to simulate rather than more professional tools like NS3, which is of low persuasion.

- The understand of this question is not enough, as a result of which I only consider part of criteria of MAC protocol rather than all.

- The mathematical calculation is not enough, as a result of which I did not get the explicit mathematical result of these criteria.

C. Future Work

It is a good choice to complete ITDMA, and that need more work in future:

- Improve this protocols performance by improving other criteria and considering it in more situations.

- Complete the mathematical analysis for both ITDMA and CSMA/CA.

- Complete the simulation of both ITDMA and CSMA/CA in NS3.

There still be a long way to get the final work, and I hope that I can do more contribution in that field after my effort.

Finally, I'd like to thanks Prof. Xinbing Wang for providing us such a wonderful class, and Prof. Xiaohua Tian for enlightening me during my work. Best wishes for you.

References

[1] Bianchi G. *Performance analysis of the IEEE 802.11 distributed coordination function*[J]. Selected Areas in Communications, IEEE Journal on, 2000, 18(3): 535-547.

[2] Shrestha B, Hossain E, Choi K W. *Distributed and Centralized Hybrid CSMA/CA-TDMA Schemes for Single-Hop Wireless Networks*[J]. arXiv preprint arXiv:1401.5528, 2014.

[3] Royo F, Olivares T, Orozco-Barbosa L. *A synchronous engine for wireless sensor networks*[J]. Telecommunication Systems, 2009, 40(3-4): 151-159.

[4] Tang L, Sun Y, Gurewitz O, et al. *EM-MAC: a dynamic multichannel energy-efficient MAC protocol for wireless sensor networks*[C]. Proceedings of the Twelfth ACM International Symposium on Mobile Ad Hoc Networking and Computing. ACM, 2011: 23.

[5] Shrestha B, Choi K, Hossain E. *A Dynamic Time Slot Allocation Scheme for Hybrid CSMA/TDMA MAC Protocol*[J].

[6] Adelson R M. *Compound poisson distributions*[J]. OR, 1966: 73-75.