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Performance Analysis of CSMA/CA Based on D2D Communication

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Abstract—This paper offers a complete idea and information about carrier sense multiple access with collision- avoidance (CSMA/CA) protocol. Firstly, what is the carrier sense multiple access protocol? and what is his job? Secondly, what is the collision- avoidance technique? and What is the effect of adding this technique to such protocol? Thirdly, knowing how to model an exact analysis to describe the protocol with it is techniques and the performance of the multiple random access method with p- persistent carrier sense multiple access and with collision- avoidance (CSMA/CA) protocol for high- speed and realizing fully- distributed (D2D) device to device communication based on IEEE 802.15.4. The collision- avoidance portion of CSMA/CA in this model is performed with a random pulse transmission procedure, in which a user with a packet ready to transmit initially sends some pulse signals with random intervals within a collision- avoidance period before transmitting the packet to verify a clear channel. The system model consists of a finite number of users to efficiently share a common channel. The time axis is slotted, and a time frame has a large number of slots and includes two parts: the collision- avoidance period and the packet- transmission period. A discrete- time Markov process is used to model the system operation. Also, it will be described by it is transmission state.

***Keywords*—**CSMA/CA, P-Persistent, D2D (device to device), IEEE 802.15.4

I. Introduction

Carrier Sense Multiple Access (CSMA) is a network protocol that listens to or senses network signals on the carrier/medium before transmitting any data. CSMA is implemented in Ethernet networks, Ad-hoc network, D2D with more than one computer or network device attached to it. CSMA is part of the Media Access Control (MAC) protocol. when a device has a packet ready for transmission, it listens to the channel [1,2,3]. CSMA works on the principle that only one device can transmit signals on the network, otherwise a collision will occur resulting in the loss of data packets or frames. CSMA works when a device needs to initiate or transfer data to another device. Before transferring, each CSMA must check or listen to the network for any other transmissions that may be in progress. If it senses a transmission, the device will wait for it to end. Once the transmission is completed, the waiting device can transmit its data/signals. However, if multiple devices access it simultaneously and a collision occurs, they both have to wait for a specific time before reinitiating the transmission process [4]. Data transmission in D2D can use CSMA/CA, and implement in IEEE 802.15.4, the basic idea is that direct D2D-based communications among devices remove the contention delay and can support longer distance [4]. Similar to other wireless technologies, D2D has improved by using the great technology in the field, and they have become more flexible in using spectrum field as a wireless technique [1]. There is different Access Modes of CSMA, showing in Figure 1:

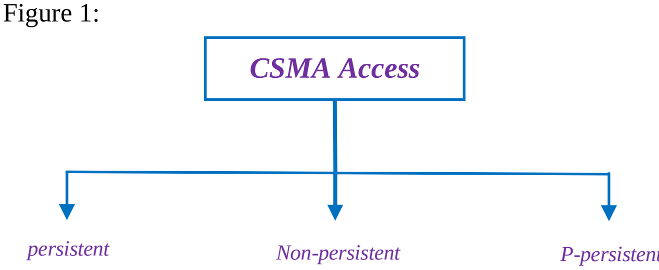

Figure 1. Different Access Modes of CSMA

This paper focus on the last type (p-persistent CSMA). P-Persistent CSMA is used in CSMA/CA systems including Wi-Fi and other packet radio systems like IEEE 802.15.4. In p-persistent CSMA, a station with frame to send senses the channel. If the channel is sensed free, the frame is send with probability p. The transmission is deferred for the next time slot with probability 1 - p. This process is repeated until the frame is sent. The IEEE 802.15.4 adopts this transmission strategy. In addition, there is number of Modifications for

CSMA Protocol [5], showing in Figure 2. However, this paper discusses the CSMA with collision.

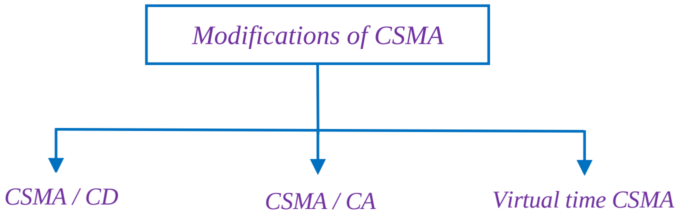

Figure 2. Modifications of CSMA

II. CSMA/CA

To take an easy example to understand the idea of CSMA/CA: Suppose NRF24L01 want to send some data, the first think is to check whether the channel is clear or not. If activates is detected it would wait for random amount of time and it will try again.

Suppose for the second time the channel will be clear and there is no activates in it so NRF24L01 will send request to send (RTS) packet to WAP to ask for exclusive opportunity to transmit, as showing in Figure 3. If WAP is still busy until this point it will tell the node “I got your request but I still busy right now, please wait. (CTS) means clear to send so the node has to wait because it is not yet clear to send. After random amount of time, the node with NRF24L01 tries again

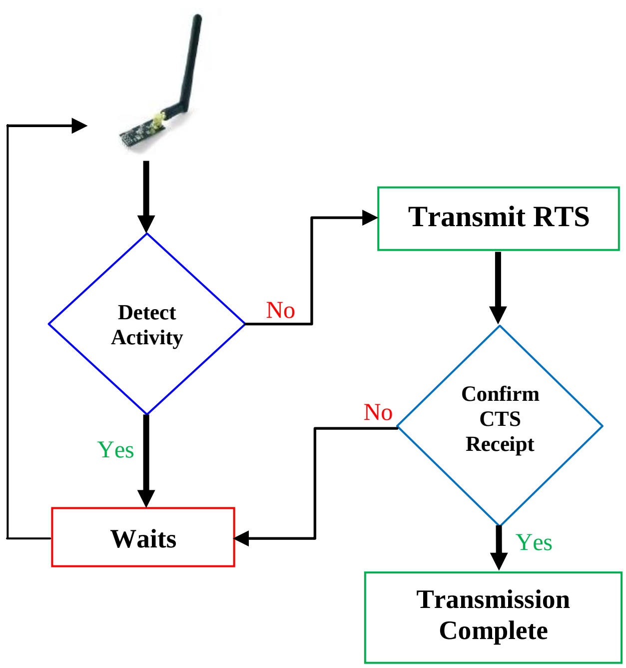

Figure 3. Process of CSMA/CA Protocol

-Nodes Structure with NRF24L01 wireless module

Many devices were created each of these device content of Arduino microcontroller with wireless module. The wireless module is NRF24L01. The module NRF24L01T can use 125 different channels which gives a possibility to have a network of 125 independently working in one place.D2D communication can use this scenario [6]. In this work NRF24L01 used, the first one is NRF24L01 as a transmitter, first device used NRF24L01 (2400 MHz) with address (00), so it can communicate with another device wirelessly at the same frequency, the other device used NRF24L01 as a receiver with address (01). The structure of D2D with NRF24L01 connection is shown in Figure 4.

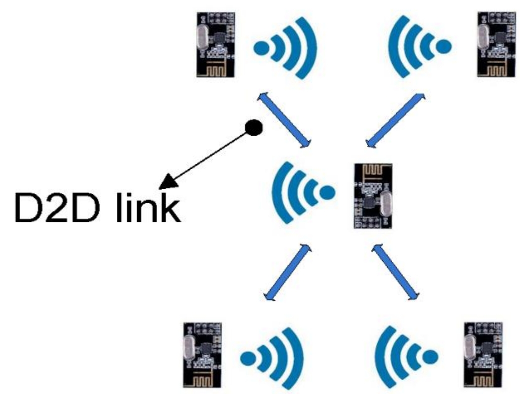

Figure 4. Structure Connection Of Nrf24l01 Module

III. Mathematical Model

The node can be in one of the following states:

Idle state (si): it is considering as the first state where the user has no frames to send. Wait state (sw): where the user has a frame to send but by sensing and listing to the channel the user will know that the channel is busy and wait transmitting states(sti) : where the user ensure after waiting the timer that the channel is empty will begin to transmit packets with $1 \le i \le n$. collided states (sci) : where the transmitting user sensed a collision with $1 \le i \le n$ and after the end of transmission. Figure 5 shows the state transmission diagram of CSMA/CA protocol.

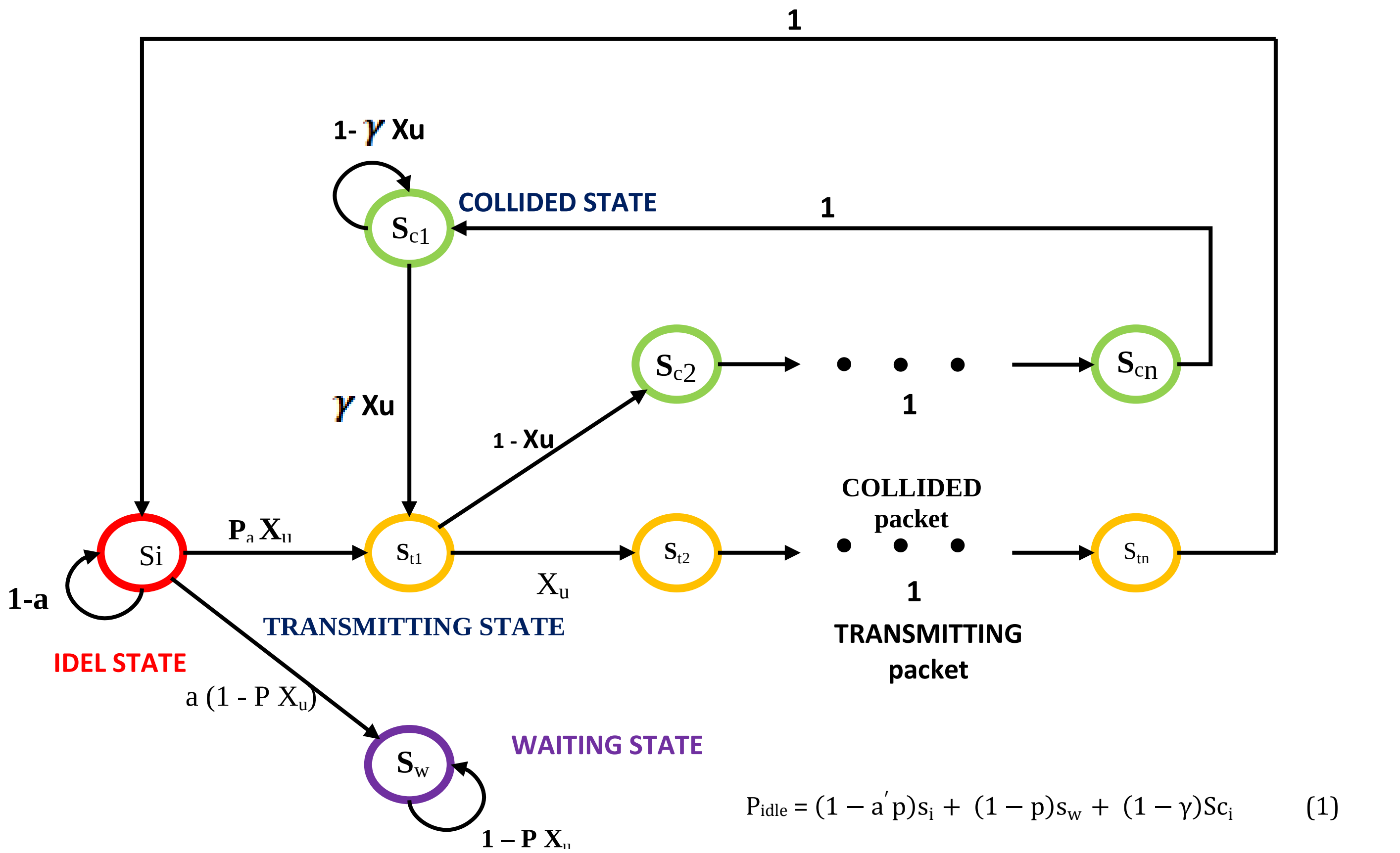

Figure 5. State Transmission Diagram

To make it clear we can take the IEEE 802.15.4 as a good example for the pure csma/ca protocol. According to the distributed coordination function (DCF) of the IEEE 802.15.4 protocol, stations accessing the channel use the basic access method, and also the optional four-way handshaking access method with an additional Request To-Send/Clear-To-Send (RTS/CTS) message exchange [5]. Under the basic access method, when a station is ready for a new data frame transmission, it first senses the channel status. If the channel is found to be busy, the station defers its transmission and continues to sense the channel until it is idle. After the channel is idle for a specified period of time called the DCF inter frame space (DIFS) period, the station chooses a random number as a back off timer.

The probability that a user will not start transmission even when the channel is sensed free is given by (1):

$$P_{idle} = (1 - a'p)s_i + (1 - p)s_w + (1 - \gamma)Sc_i \qquad (1)$$

Where a'=a/n is the probability that during a time step a station requests a transmission, p is the persistence probability when the user is waiting for the channel to be free, and γ is the probability that a collided user starts a transmission. According to that, excepting the tagged user, the probability all untagged users will not start transmission is given by (2) [4]:

$$X_u = [(1 - a'p)s_i + (1 - p)s_w + (1 - \gamma)Sc_i\,]^{N-1} \qquad (2)$$

In other hand, In CSMA/CA protocol the listening begins after first collision and can note that There are several collided states since a user continues to transmit after a collision has taken place. As shown in Figure 6, the time immediately after the DIFS period is slotted. the timeslot duration is at least the time required for a station to detect an idle channel, plus the time required to switch from listening to transmitting mode. The back off timer is decreased by one for each idle slot, stopped if the channel is sensed busy, and then reactivated if the channel is idle again and remains idle for more than a DIFS time period. When the back off timer reaches zero, the data frame is transmitted [7,8].

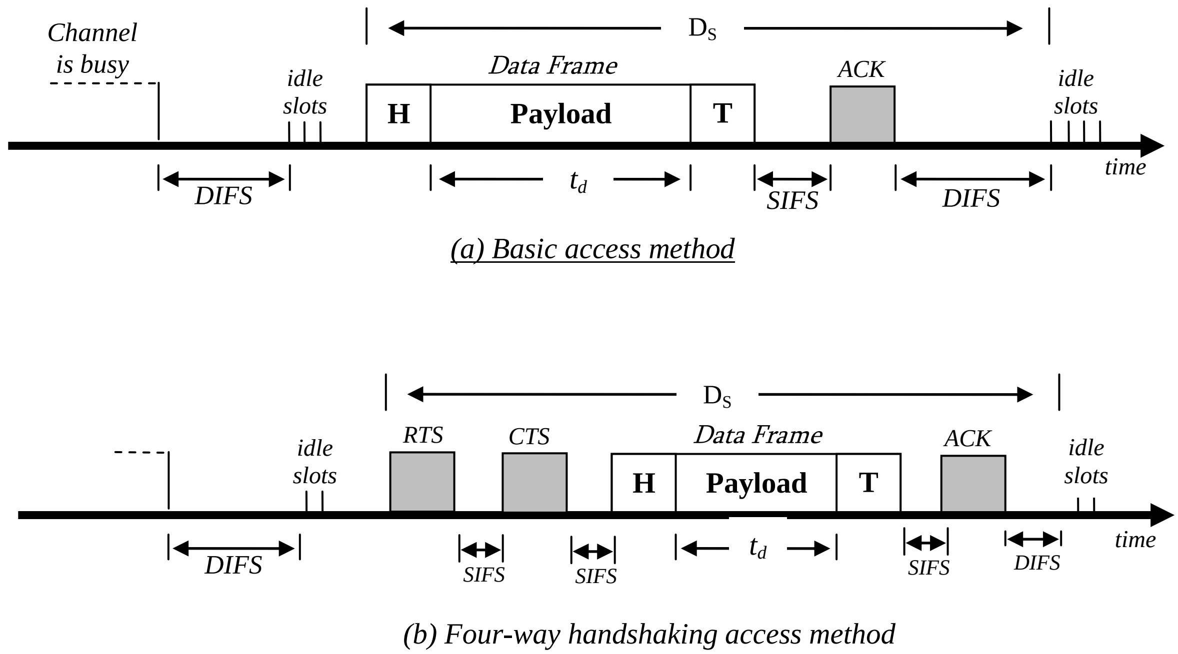

Figure 6. The IEEE 802.15.4 access methods

The choice of the random number for the back off timer is based on the binary exponential back off algorithm. For each unsuccessful transmission attempt, the station increases its back off stage count and doubles its CW, until the station reaches the predefined maximum back off stage, M. At that stage, CW ceases to increase. To determine whether a data frame transmission is successful, after its completion, a positive acknowledgement (ACK) is transmitted by the receiver. ACK is transmitted after a short inter frame space (SIFS) period upon receiving the entire data frame successfully. If ACK is not detected within an SIFS period after the completion of the data frame transmission, the transmission is assumed to be unsuccessful, and a retransmission is required. When the back off timer of a station reaches zero, the station first transmits an RTS frame to request a transmission right. Upon receiving the RTS frame, the receiver replies with a CTS frame after a SIFS period. Once the RTS/CTS information is exchanged successfully, the sender transmits its data frame. After a successful transmission, a station must perform a compulsory DIFS deference and back off even if it has no queued data frame in its local buffer. This process is often known as "post-back off", it ensures that consecutive transmissions are separated by at least one back off interval. If a new data frame is generated after the post-back off procedure, the data frame may be transmitted immediately if the channel has been sensed idle for a period longer than the DIFS [9].

And as showing below in (3) the distribution vector considered at equilibrium is:

$$s = [s_i \ s_w \ s_{t_1} \ s_{t_2} \ \ldots \ s_{tn} \ s_{c_1} \ s_{c2} \ \ldots \ s_{cn}]^t \qquad (3)$$

Also, the corresponding transition matrix of the channel [9]:

$$P = \begin{bmatrix} 1-a & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ a(1-pXu) & 1-pXu & 0 & 0 & 0 & 0 & 0 & 0 \\ apXu & pXu & 0 & 0 & 0 & \gamma Xu & 0 & 0 \\ 0 & 0 & Xu & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1-Xu & 0 & 0 & 1-\gamma Xu & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 1 & 0 \end{bmatrix} \qquad (4)$$

The throughput is given by the equation:

$$Th = nNTn \qquad (5)$$

CSMA/CA keeps transmitting frames even when collisions have taken place. Therefore, precious bandwidth and time is wasted transmitting frames while CSMA/CD stops the transmission

The access probability for a user in the CSMA/CA protocol is given by [10]:

$$P_a = Th / Na \tag{6}$$

The average number of attempts for a successful transmission is [9]:

$$n_a = \sum_{i=0}^{\infty} i\,(1 - p_a)^{i}\, p_a$$
$$= 1 - P_a / P_a \tag{7}$$

The average energy required to transmit a frame is estimated as [11]:

$$E = E_0 \sum_{i=0}^{0} (i + 1)\,(1 - p_a)^{i} p_a \tag{8}$$

IV. MARKOV CHAIN

This paper presents a study of Carrier sense multiple access with collision avoidance CSMA/CA using a Markov chain method. On one side the paper presents a complete description of how CSMA/CA work and how the collision avoidance technique effects the whole operation of the packet that transfers between independent station. On the other side, the paper analyses the Modelling of the system with the state transmission diagram and reviewing a case study that related to one of Common examples of wireless systems using CSMA/CA like (IEEE 802.15.4). This analysing and reviewing reveals that the CSMA/CA protocol, somehow similar to the state dependent M/M/1/k queue The queue size of the SDM/M/1/k queue is analogous to the number of active stations, as showing in Figure 7:

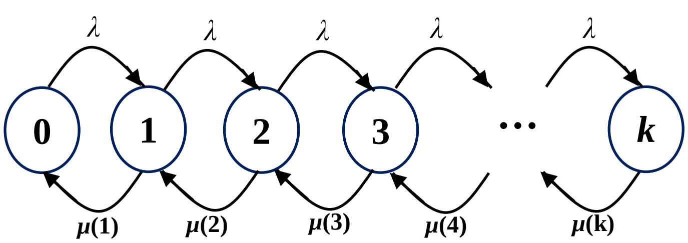

Figure 7. State Transmission M/M/1/K

V. SIMULATION AND RUSELTS

In this experiment of CSMA/CA module there are 43 random distributed nodes has been taken, so the data arrived as shown in Figure.8 represent the size of data for each node before the queue. In case of sigma = 2 and 20*4 packet length, the probability of each node approximately are equalize after 11sec. The Effective Bandwidth per Node with respect to delay for 43 node module of CSMA/CA in case of sigma = 2 and data rate = 250 kbps are shown in Figure. 9, the delay ratio was decreased for collision- avoidance as well as the bandwidth. The stability of module in Figure. 10 for average changes will be 11 sec. The convergence state after applying the total attempts was shown in Figure. 10. Each node in waiting state has idle energy level whilst the maximum energy for transmission state, the discribtion of all energy levels shown in Table.1.

Table 1. State Parameters

STATE	POWER LEVEL
Sleep	1
Sense	20
Tx	50
Rx	45
Idle	5

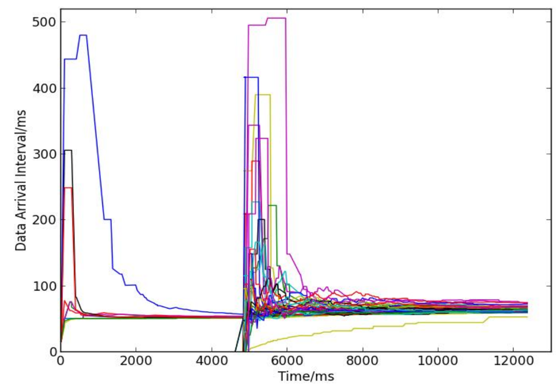

Figure 8. Data received rate

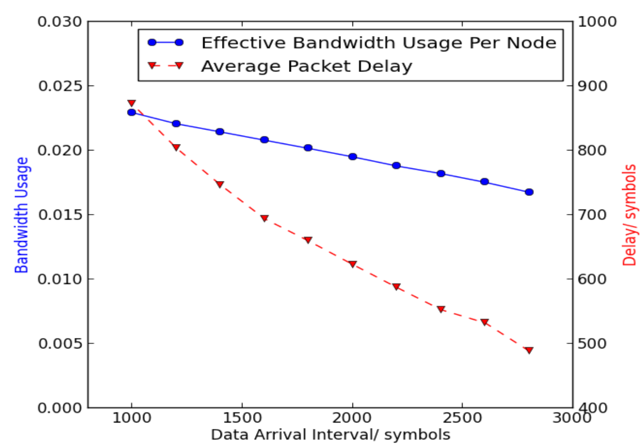

Figure 9. Effective Bandwidth

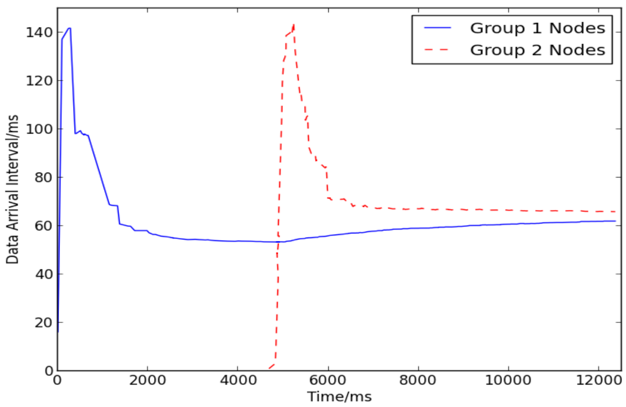

Figure 10. Average Change

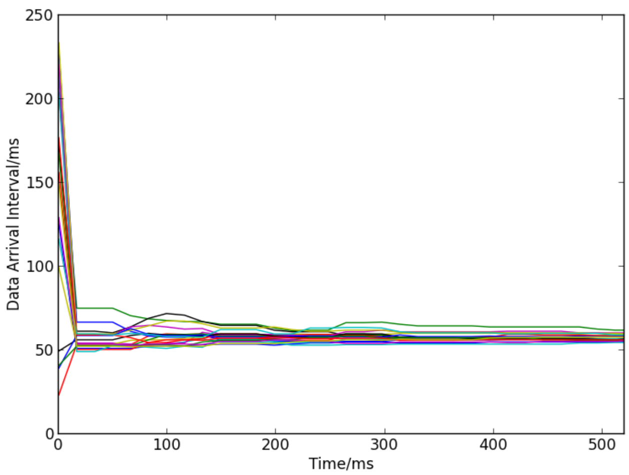

Figure 10. Convergence State

CONCLUSIONS

This work exhibited a simulative appraisal of the CSMA/CA with Python 2.7, for performance checking applications. There are five levels (Sleep, Sense, TX, RX and Idle), the execution of customary messages specifically, in the sensible situation (i.e., on the off chance that b) despite the fact that the start to finish postponements of the basic messages somewhat increment of the average of data arrival according of channel capacity to avoid the collision. The transmission time frame is scheduling for the probability of chain model, so the planning limitations of the basic messages are still met. The data rate that taken is 250 kbps, this rate, denoted μ(i), that a station is served is a function of the number of active stations, denoted i. Therefore, we consider state dependent service rate in our queue. The Poisson arrival in the M/M/1/k queue is analogous to the Poisson process associated with points in time in which stations switch from idle to active mode, the rate is denoted λ. This simple example assumes a Poisson arrival process and Markovian state dependent service. This paper study the performance of the CSMA/CA and give the good example to get hardware implementation using NRF24L01 with node to enforcement the queuing system in D2D communication with a popular of nodes.

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