IJARSCT

ISSN (Online) 2581-9429

International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)

IJARSCT
Impact Factor: 6.252

Volume 2, Issue 1, August 2022

ALOHA Protocol

Mr Pradeep Nayak[1], Nandan M R[2], Nayana T[3], Ravindra Reddy[4]
Assistant Professor, Department of Computer Science and Engineering[1]
Students, Department of Information Science and Engineering[2,3,4]
Alvas Institute of Engineering and Technology, Mijar, Karnataka, India
4al20is032@gmail.com, mrnandan062@gmail.com

Abstract: *The throughput of a 2-D optical code-division multiple-access (OCDMA)/unslotted ALOHA (U-ALOHA)/channel load sensing protocol network using an optical hard limiter and channel code was examined. This approach presupposed a constant message length and a single user class. However, multimedia traffic with variable frequency is the current and future focus of networks. message length and the distinction between real-time and non-real-time user classes. In this essay, we propose a 2-D OCDMA/U-ALOHA network with access control and two classes of variable users. message size We consider the number of fixed-length packets in a message to be geometrically distributed and carry out access control by allocating two user classes with various access probabilities of obtaining permission. The numerical results demonstrate the high priority user class, such as real-time data traffic) can sustain maximum. A possible alternative to local area networks (LANs) and broadband optical access networks for greater capacity in response to the rapidly increasing volume of multimedia data traffic, the suggested network protocol has the potential to achieve 100 Gbps. The scalability and stability of Lora networks have faced additional hurdles as a result of the exponential development of IoT devices. The Lora network's collision issue is major one right now. This is due to the fact that LoRa WAN's MAC layer protocol is mostly based on the Pure ALOHA is too-simple a mechanism to handle collisions. The flexible frame spacing The pure ALOHA algorithm is where ALOHA is optimised, and it can successfully minimise collisions.*

Keywords: ALOHA algorithm

I. INTRODUCTION

Larger-capacity local area networks (LANs) and broadband access networks are urgently needed to accommodate the massive quantity of developing multimedia data traffic as a result of the corporate sector's explosive development in demand for broadband services. An alternative to meet the needs is the gigabit passive optical network (PON). However, it necessitates network synchronization and raises the price of network deployment. Due to its asynchronous transmissions, which make network deployment simple, and its random access nature, which is adaptable to integrating heterogeneous data traffic, optical code-division multiple-access (also known as optical CDMA, OCDMA) is a promising replacement for LANs and broadband optical access networks. This paper's primary goal is to provide an energy-efficient, high-throughput, scalable MAC protocol for M2M communication. ALOHA-NOMA is a strong candidate for a MAC protocol that can be used for low complexity IoT devices because of its simplicity, superior throughput provided by non-orthogonal multiple access (NOMA) [4], and capacity to resolve collisions by employing successive interference cancellation (SIC) receivers. It is important to note that NOMA can get beyond ALOHA's fundamental drawbacks, which are its limited throughput and high collision rate. Wireless communication is used in electronic shelf labels (ESL) to constantly change the material on shelving displays. In place of traditional paper price tags, shops now use electronic shelf labels to display product prices, sales specials, and other information. They usually have a liquid crystal display or an e-paper display that shows the statistics, and they are affixed to the front edge of a shop shelf. They adhere to the dynamic pricing model to enable quickly fluctuating rates and synchronize the cost of the product across the nation, region, and city. They are appropriate for grocery stores, major utility store chains, and mega marts, among other types of retail establishments. They make tracking products more convenient. Promotions and adverts are simple to manage, and clients are drawn to the vivid display.

DOI: 10.48175/568

II. RELATED WORKS

By using LoRaWAN with FHSS (frequency hopping spread spectrum) to reduce the collision problem by using a smaller SF, Sungryul Kim optimised the pure ALOHA with the gradient projection method for optimal distribution of spreading factors (SFs), and the maximum number of ENs can achieve a maximum throughput of 62% while ignoring the downlink DC [4]. Gyubong Park aimed to increase both energy effectiveness and throughput. Only 20 data samples were used in this implementation, which relied on reinforcement learning because the algorithm needed a lot of time to train. This technique worked well for lengthy transmissions and very low data rates. As a result, although energy efficiency increased, throughput declined by up to 15% [5]. The identical SF transmissions were examined by Dimitrios Zobras in By assigning SFs to nodes while maintaining the duty cycle, separate time slots and different SF transmissions can be made in concurrently [6]. According to Jetmir Haxhibeqiri, pure ALOHA will suffer losses of about 90% when the number of nodes per gateway rises to 1000. However, LoRaWAN will have a 32% coverage area. Losses could be reduced by bringing the application layer's DC below the permitted radio duty cycle of 1% [7].

To establish the slots for data packets for acknowledgment, Tommaso Polonelli developed the synchronised ALOHA protocol. This protocol uses clock synchronisation between end nodes. S-LoRaWAN was created for low-cost, low-power Internet of Things devices. By deploying 24 nodes, the packet collision was decreased to 26% for peak traffic, and throughput increased to 5.8 in real life.

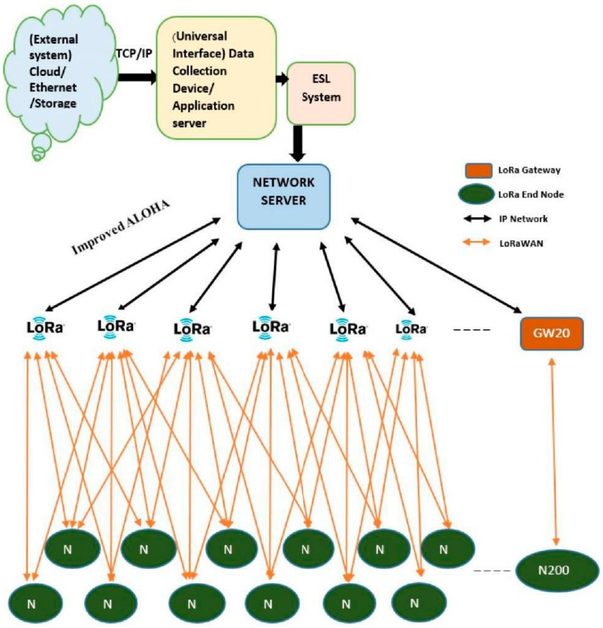


Figure .1

III. METHODOLOGY

The method consists of enhancing pure ALOHA, allocating ENS for SX1276, and applying an acknowledgment synchronization mechanism to maximize throughput.

3.1 Improved ALOHA

For pure ALOHA, GW1 and other GWs will collide if they both send a frame at the same time (t = 0) or interval. The amount of time needed for a collision is depicted in Figure 2. As a result, 2Tfr is the window of vulnerability during which every GW may send data whenever they are available. Every GW transmits data without first validating the channel's state, which raises the probability of data frame collision. Only the delivered frame receives an ACK; frames that have collided or overlapped do not. The GWs wait for the damaged frame for an arbitrary amount of time before attempting to retransmit it until it does so successfully.

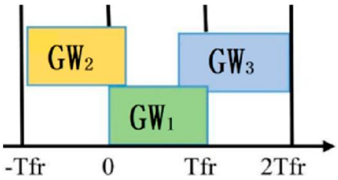


Figure 2. Pure Aloha

To derive the efficiency of the pure ALOHA channel, maximize *h* for G.

$$\mathrm{d}h/\mathrm{d}G = 0\ )\ \mathrm{d}(Ge2G)/\mathrm{d}G = 0$$

where G's finite value is utilized to examine the network's throughput. G denotes that a Tfr must be used for transmission by half of the GWs. Essentially one GW should transmit in 2Tfr for best efficiency. Pure ALOHA has a maximum efficiency of 18.39%.

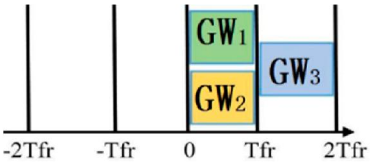


Figure 3. Slotted Aloha

3.2 ALOHA is Slotted.

It makes sense that slotted ALOHA is twice as efficient as pure ALOHA. The throughput consequently doubles [6–8]. By transmitting the frame blindly—that is, without using channel sensing—LoRa defines the same system as pure ALOHA. ALOHA employs the Poison process with an average rate of G tries per slot for a sizable LoRa network. The ENs with the same SF will collide if the packet length is maintained, and G represents the average attempt per time slot.

3.3 Improved Acknowledgment

The EN will wait for retransmission after the GW makes numerous unsuccessful communication attempts. The GW will, however, send a fresh message to the EN and the EN will contact the ACK for the lost message as a result of the ACK drop at the GW. Due to GW's half-duplex nature, it is unable to simultaneously listen to the channel during the uplink and downlink, which results in faulty implementation of ACK's message integrity code (MIC). This particular DC cannot manage the frame transmission interval and transmission response (pure ALOHA). The time of a frame and an ACK cannot be precisely determined by choosing a random delay between 1 and 3s. are greater than a second, a considerable likelihood of recurring collisions will happen. A frame or an ACK. The network's ability to scale will be constrained by an increase in the random delay, which is a fixed interval (slotted ALOHA). Any two transmissions with the same CF, SF, and BW that overlap in time at the EN will collide and lose data. To solve this issue, the payload's ToA is subtracted from the ACK's locality delay, and vice versa, to synchronise the EN to the GW's clock. The GW will resynchronize the EN, which is based on synchronisation rather than retransmission, by sending six symbols of the preamble in the event that the packet is lost rather than retransmitting it. The EN's location affects the ToA and ACK's timing. As a result, synchronisation times for ENs at higher SFs are longer than those for ENs at lower SFs. The same approach is used for uplink and downlink.

Algorithm 1. ALOHA

```
Input: ENs, GWs, D, DC Initialize: t, _, BW, RSSI Ensure: $h$
for t = 7,8, . . . ,12 do
Calculate ENs' RSSI for each cluster via Table 5
Estimate ENs' $r$ using each combination of GWs via Table 6
if (DCLimit > DC) and (ToAMLA > ToAt)
then
GW transmits data to EN
else if (DC == DCLimit) & (ToAMLA > DC)
```

```
then
Higher the BW
else if (Sat.MLA > Sat.Limit) & (ToAMLA < DC) then
Lower the BW
else
alert unsuccessful transmission
end if end for
ACK==ACKLimit
GW synchronizes EN
```

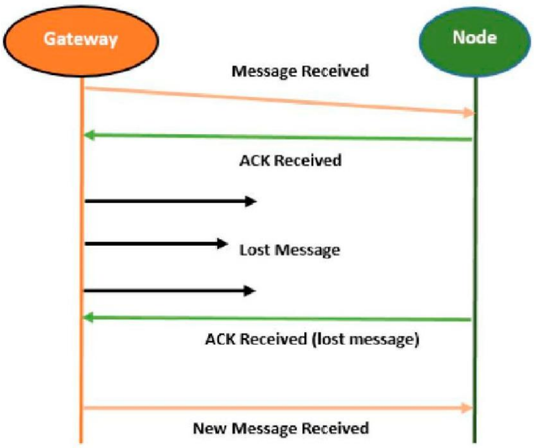


Figure 4. Failure of message integrity code.

Algorithm 2. Acknowledgment

```
Input: DC, D
Initialize: ENs/SF to GW via Table 2 ACKLimit = ToA + ACK's time + Synchro. via Figure 5
Ensure: ACKCNT = 0 for all ENs in the range of GW
for UL transmission do
ACKCNT = ToA + ACK's time
ACK not received then ACKCNT== ACKLimit NS sends six symbols of preamble for Synchronization via Table 3
end for
for ACKCNT _ ACKLimit + Synchro. do RSSI Estimation to find the locality of EN via Table 4
end for
for DL transmission received do
ACKCNT = 0
end for
```

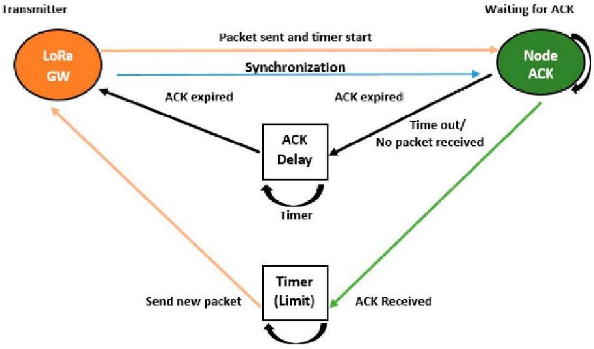
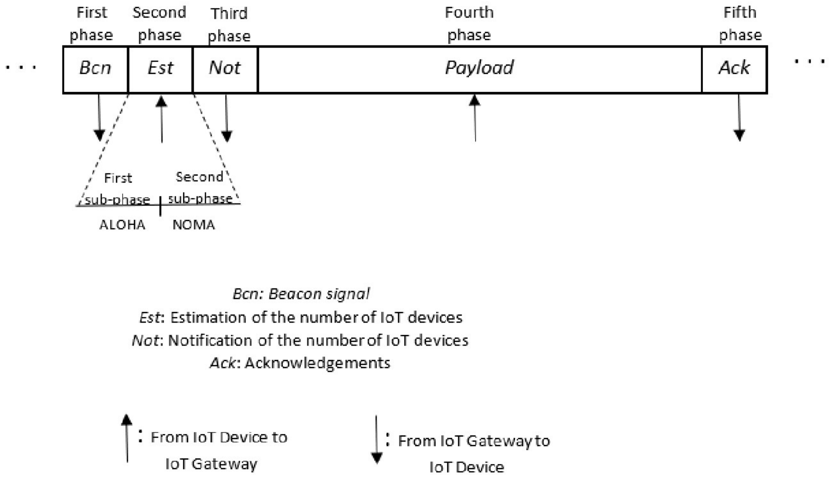


Figure 5. Synchronization acknowledgment.

IV. DYNAMIC FRAME STRUCTURE FOR ALOHA-NOMA PROTOCOL

Determining the appropriate power levels of IoT devices is one of the major practical issues in the proposed ALOHA-NOMA protocol to be used in IoT applications; otherwise, the signals cannot be properly differentiated at the gateway by a SIC receiver. In fact, before ALOHA-NOMA information transfer starts for IoT applications, just the power level modifications need to be made. To overcome this difficulty, a dynamic frame structure that is highly adaptable to the fluctuating number of devices is created; as a result, the same frame structure is used when a group of IoT devices joins or leaves the network. A plan like this offers a lot of adaptability to shifting network settings. Comparing this structure to that of TDMA or FDMA, which The addition of a new user may totally alter the structure of the frame as a whole, necessitating the assignment of at least one slot to the new user. The suggested frame structure consists mostly of five phases and is periodic. Fig. 2 provides an instance of the suggested periodic frame construction. So, a beacon signal is the first thing the gateway sends out. The next step is for IoT devices that have packets to transmit to send "dummy" packets (packets devoid of any data content), which aid the gateway in estimating the total number of active devices in the channel. It should be noted that earlier demonstrated how to determine the amount of signals using multiple hypothesis testing. Third, each IoT device correctly adjusts its transmission strength when the transmitters get a broadcast of the entire number of devices. Each device has a number or identity that corresponds to the appropriate power level, as you can see. Fourth, every IoT device sends a packet to the gateway, and finally, the messages that have been detected are acknowledged. For each device to know whether its packet was successfully received, the fifth phase, an ACK packet, can include the specific IoT device numbers corresponding to successfully decoded packets. Due to the fact that the length of phases is independent of the number of IoT devices, this frame structure is maintained while the number of IoT devices changes.

Even if the first three phases and the ACK could be thought to reduce throughput efficiency, they are still much shorter than the fourth phase or payload. For additional information on the protocol, it should be noted that after the gateway sends a beacon signal, all IoT devices that submit packets in this frame broadcast concurrently to the IoT gateway using the ALOHA protocol. The SIC receiver is then configured to decode this number of IoT devices using NOMA after the IoT gateway estimates the number of IoT devices through multi-hypothesis testing. Observe that multi hypothesis testing would be more difficult to implement if all IoT devices were registered to the gateway; however, this could significantly lengthen the control phase. After estimating N, the total number of IoT devices, the gateway's SIC receiver decodes N's strongest signal.



In the third step, the gateway decodes these packets and broadcasts the number of IoT devices with these addresses/IDs, assuming that IoT devices provide their address/ID in the dummy packet. Devices that cannot identify their address or ID do not send a payload. When a device recognises its address or ID from a gateway message, it modifies its power in accordance with the power back-off strategy suggested in [14]. They alter their power level in particular with n, where n is a uniform random variable between -N and N, and is a predefined value. To improve the network, each IoT device chooses a number n at random and modifies its transmission power. where the transmitters are required to have varying power levels, the quality of the SIC receiver. The active IoT devices can slightly raise their transmit powers in the subsequent round if the gateway does not recognise their address or ID. This will also have an impact on the results of the multi-hypothesis testing. All IoT devices that had their address/ID recognised by the gateway transferred the payload data to it in the fourth step. The fourth phase of the suggested frame structure can be regarded as pure NOMA, as you may have seen. In the final phase, the properly discovered packets are acknowledged. Periodically, this practise is repeated.

V. THROUGHPUT OF ALOHA-NOMA

Determining the number of IoT devices in the second phase would affect one of the most important components of the proposed frame structure. Since only 18% of IoT devices can typically be recognised at a time, the performance would be subpar if only pure ALOHA was used in the second phase. In the second stage of the suggested frame structure, the ALOHA protocol is swapped out for ALOHA-NOMA to solve this issue. As a result, multi-hypothesis testing is used to estimate the number of devices based on the superposed signal strength as was done in . It should be noted that the goal of this phase is merely to estimate the number of devices, not to find the packets. It is set to decode on the SIC receiver. Signals and packets in this quantity are found. It is It's important to note that each round the strength of Each gadget fluctuates randomly and individually, so Using these power sources, the SIC receiver can operate effectively differences. This section's primary goal is to describe the throughput increase of ALOHA-NOMA compared to pure ALOHA. Using NOMA, the ALOHA throughput can be significantly boosted, enabling multiple users to effectively communicate with the gateway at once during the vulnerable period. When there are N or fewer arrivals (transmissions), which occur with probability, a SIC receiver that can identify N transmissions, or a SIC(N), will achieve successful reception.

VI. NUMERICAL RESULTS

The numerical evaluation of the ALOHA-NOMA throughput study provides additional context for various N values. The throughput maximum determined by the performance metric (5). In other words, (5) is assessed for various N values. As seen in Figure 3, the ALOHA-normalized NOMA's throughput rises with a slope that is larger than linear when N is between 1 and 5. You'll see in Fig. 3 for the ALOHA-NOMA system that the well-known ALOHA throughput, which is 0.18, is seen at N = 1. In Figures 4 and 5, the normalised throughput is examined for two different numbers of active transmitters, N = 20 and N = 100. Be aware that Figures 4 and 5 are the expansion of Figure 3 for high values of N.

VII. LORA AND LORAWAN

The LoRaWAN protocol defines the sending and receiving rules of the MAC layer of LoRa devices, including the frame format used by the terminal to communicate with the gateway (request connection frames, data frames, etc.), the receiving window of the terminal device, the MAC command of the gateway, the retransmission mechanism, the rate adaptation mechanism, and the error control mechanism. LoRa is a spread spectrum modulation technique on the physical layer.

7.1 Network Architecture and Terminal

Usually, a star network is used by LoRa. The gateway, which can connect to hundreds of terminal nodes, is directly attached to the node. A web server can receive data from an endpoint via one or more gateways. Class A, Class B, and Class C terminal device types are the ones that LoRaWAN specifies. With Class A, the terminal actively communicates with the gateway in accordance with its own needs. Only one of the two brief downlink receiving windows that follow the terminal's uplink transmission can receive a response from the gateway[9]. The terminal in Class B opens a second receiving window at the designated time in addition to the random reception window of Class A. The gateway must send a time synchronisation beacon to the terminal. the opening for receiving During transmission, the Class C terminal is only momentarily shut off; otherwise, it remains operational. As a result, Class C uses more energy than Classes A and B, but it also has the quickest time before the server issues the terminal.

7.2 Retransmission and Rate-adaptation Mechanism

For communication between nodes and gateways, a variety of frequency bands and speeds are available. The SF (Spreading Factor) is the major factor that influences the choice of various rates. Typically, devices at greater distances must choose a larger SF in order to have higher sensitivity, but doing so will result in a reduced transmission rate. The number of retransmissions following a failed data packet transmission can be controlled by the LoRa terminal node, and is typically between 0 and 7. When all possible retransmissions have been made and recognition is still being withheld, the rate is decreased to increase the transmission distance.

VIII. LO-RA-WAN ANTI-COLLISION ALGORITHM BASED ON DYNAMIC FRAME-SLOTTED ALOHA

8.1 Dynamic Frame-slotted ALOHA Algorithm

By dynamically modifying the frame length after the initial frame, the DFAA (Dynamic Frame-slotted ALOHA Algorithm) is based on the frame-slotted ALOHA. The technique first determines the starting frame length based on the overall node count. In order to dynamically set the length of the subsequent frame, it is calculated how many nodes failed to send after the initial transmission. The calculation of the ideal frame length is the algorithm's main step. Too little frame time will increase the likelihood of a collision. The time slot will be squandered if the frame length is too long. The slot length times the number of nodes is typically used to calculate the ideal frame length for various node counts. $F=t*n$ (1) (1) F stands for frame length, t for slot length, and n for node count. The number of nodes that have not been successfully transferred determines the length of the subsequent frame after one frame has ended. The minimal estimate approach, Poisson estimation method, collision probability estimation method, Chebyshev estimation method, etc. are some of the estimation algorithms for the number of nodes that are unsuccessfully sent due to collisions. This study prioritises the use of the highly precise Chebyshev estimation procedure, disregarding the difficulty of the calculation.

8.2 Algorithm Implementation

The communication between the node and the gateway in Lo-Ra-WAN can either be deemed successful or unsuccessful. However, if the LoRa preamble is identified through the channel, the preamble detection technology can separate the failure into idle slot and collision slot. A collision slot is one that has a prelude; otherwise, it is an idle slot. When the frame length is F, the idle slot, the single slot, and the collision slot are each, respectively, c0c1ck, and the estimated number of nodes is n, according to the Chebyshev estimation procedure. Calculations are made to determine the expected values of the idle slots, single slots, and collision slots for the various theoretical values of n.

8.3 Result of Experiment

The experiment is based on the LoRa network model on ns3 provided by [11], which includes the LoRa's channel model Spectrum Channel, and the physical layer LoRaWAN Phy and MAC layer LoRaWAN Mac of the Class A node and the gateway, as well as the device layer LoRaWAN NetDevice of the terminal node and gateway and the application layer LoRaWANEnd Device Application of the terminal node, LoRaWANGate They may essentially mimic a genuine LoRa network.

IX. LORAWAN SIMULATION MODEL

The LoRa network's PDR (Packet Delivery Ratio) performance evaluation criterion measures the proportion of packets sent by the terminal node to those received by the target gateway; in other words, PDR is calculated as follows: PDR = the number of packets successfully transmitted / the total number of packets sent. It is a statistical indicator of accurately transmitted packets that reflects a network's dependability and congestion. System efficiency is another evaluation criterion that measures a system's overall performance. It is calculated as the ratio of the number of successfully communicated time slots to the total number of time slots, or system

efficiency = successfully transmitted time slots / total time slots.

Relationship between PDR and period of pure aloha and DFAA:(a)n=1000;(b)n=2000

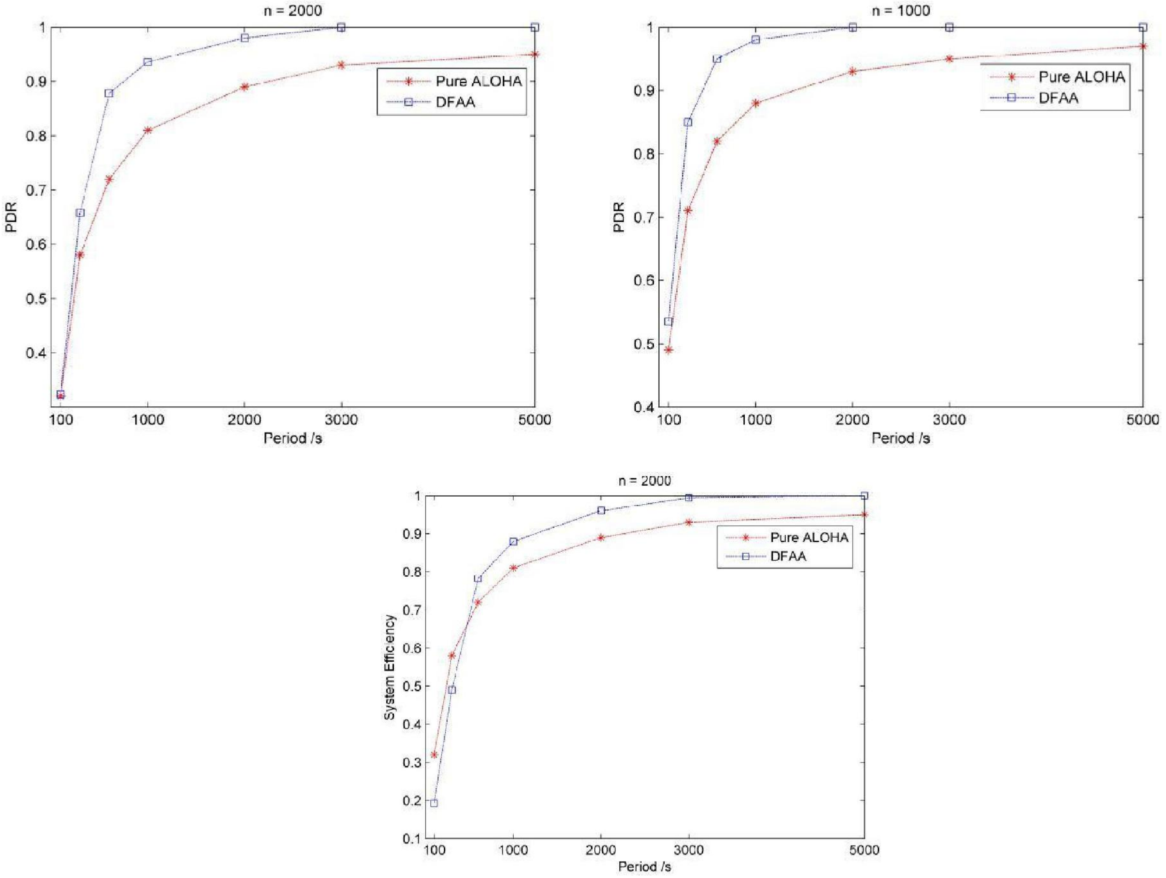
As the period length grows, the PDR of the DFAA is always higher than the PDR of the pure ALOHA algorithm whether the number of nodes is 1000 or 2000. Figure

3 also demonstrates that the DFAA has somewhat worse system efficiency than the pure ALOHA method. Currently, all nodes in the pure ALOHA algorithm are only sent once because the system efficiency primarily depends on time

DOI: 10.48175/568

slot use, however nodes that failed to transmit are sent again in the DFAA. Since there are more transmissions overall in the latter than in the former, there are also more slots available. There is no absolute advantage in the transmission success rate of short periods of time.

Relationship between System Efficiency and period of pure aloha and DFAA:(a) n=1000; (b) n=2000



Advantages :

- Doubles the efficiency of Aloha.
- Adaptable to a changing station population.

Disadvantages :

- Theoretically proven throughput maximum of 36.8%.
- Requires queuing buffers for retransmission of packets.

X. CONCLUSION

The LoRaWAN technology is thoroughly explained in this study, along with its drawbacks in terms of collision processing. It is then suggested that dynamic frame-slottedALOHA anti-collision algorithm be combined with LoRaWAN by customising the algorithm using preamble detection technology. Next, determine the ideal frame length for the following frame using the Chebyshev estimate method. The paper then conducts a thorough study of the dynamic frame ratio. According to the simulation test on ns-3, the optimal starting frame ratio for LoRaWAN is between 50% and 70%, and the system efficiency can be increased by roughly 7%. It is evident that the algorithm can enhance the system's overall performance and the dependability of LoRaWAN.The goal of this study is to optimize pure ALOHA for LoRa-based ESL. Increasing the amount of GWs utilising MLA during the simulation results in varied behaviour as opposed to just one GW. The network's performance suffers without MLA for a while. GW with rising SF and ENs, whereas for several GWs, network performance utilises K-mapping to enhance. The network receives the largest boost when the BW is reduced. successful transmission rate but results in increased Preamble and ToA, slowing the network. Additionally, packets that take longer than the DC to process are rejected.

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