A Review on Network Optimization for ALOHA Networks

Minakshi Makode[1], Prof. Prof. Pankaj Raghuwanshi[2]

Abstract— ALOHA Networks happen to be an effective data transfer protocol for ultra narrowband (UNB) networks. Enhancing throughput in Slotted Aloha, a contention-based multiple access protocol, involves optimizing the system to achieve higher efficiency in packet transmission. Slotted Aloha divides time into discrete slots, allowing each station to transmit data packets only at the beginning of a time slot. This prevents collisions that can occur in unslotted versions of the protocol, where stations can attempt to transmit simultaneously, leading to packet loss and reduced throughput. This paper presents a review on the various techniques for optimizing ALOHA networks primarily focusing on throughput enhancement.

Keywords— Ultra Narrowband (UNB), ALOHA, Slotted ALOHA, Throughput.

I. INTRODUCTION

Throughput in Slotted Aloha can be enhanced by optimizing the slot size. Larger slots allow for a higher probability of successful transmission but can lead to increased idle time if slots remain empty. Conversely, smaller slots reduce idle time but may increase the likelihood of collisions. Finding the optimal slot size involves balancing these trade-offs to maximize throughput. Enhancing throughput in Slotted Aloha involves a combination of optimizing slot size, introducing backoff mechanisms, adapting slot allocation, incorporating carrier sensing, integrating with other protocols, and evaluating performance through simulation and experimentation. These strategies aim to improve the efficiency of packet transmission and maximize overall throughput in contention-based multiple access networks.

Some common throughput enhancement mechanisms are:

Backoff Mechanisms: Introducing backoff mechanisms can further enhance throughput in Slotted Aloha. When a collision occurs, stations involved in the collision can wait for a random period before attempting to retransmit. This randomized backoff reduces the probability of collisions repeating in subsequent slots, improving overall efficiency and throughput.

Adaptive Slot Allocation: Another approach to enhancing throughput involves adaptive slot allocation. Instead of fixed slot sizes, the system dynamically adjusts slot durations based on network conditions such as traffic load and channel capacity. By allocating more slots during periods of high demand and fewer slots during low demand, the system can optimize throughput while minimizing idle time and collisions.

Carrier Sensing: Incorporating carrier sensing mechanisms can also improve throughput in Slotted Aloha. By detecting the presence of other transmissions before attempting to transmit, stations can avoid collisions and maximize the utilization of available slots. Carrier sensing can be implemented using techniques such as listen-before-talk (LBT) or clear channel assessment (CCA), depending on the underlying transmission medium.

Combining Slotted Aloha with other Protocols: Throughput enhancement can be achieved by combining Slotted Aloha with other access control protocols. For example, the use of a hybrid protocol that switches between Slotted Aloha and reservation-based protocols like TDMA or CDMA can leverage the advantages of both approaches to optimize throughput in varying network conditions.

Performance Evaluation and Simulation: Finally, evaluating the performance of enhanced Slotted Aloha systems through simulation and experimentation is crucial. By modeling different configurations and parameters, researchers can assess the impact of throughput enhancement techniques and identify optimal strategies for real-world deployment.

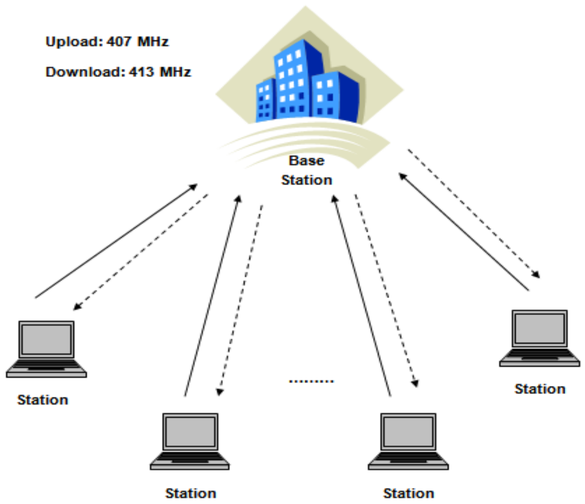

Fig.1 Model for the ALOHA Network

The object of this paper is to propose a novel spread slotted Aloha system with CLSP and show a significant improvement of the throughput performance even in the presence of access timing delay. The channel is to be continuously sensed or monitored for the collision or colliding conditions prior to packet data transmission.

II. PREVIOUS WORK

This section presents the noteworthy contribution in the domain:

In [1], Ana Paula Teles Ribeiro da Silva at al. proposed a technique for computation of enhanced throughput for slotted ALOHA systems employing the use of cognitive behaviour of ALOHA systems. The cognitive radio network (CRN) approach helped in the estimation of channel collisions better by estimating the channel state response. The authors consider a CRN with the Slotted Aloha protocol, and in order to improve the system's performance, they also proposed the use of an adaptive modulation technique. Finding the optimum switching points between neighbouring modulations is a key issue of the adaptive modulation system.

In [2], Claire Gousaud et al. put forth a study on random un-slotted Time Frequency ALOHA. It finds its foundation and basis on the Internet of Things. It is a relatively new and fresh concept allied to networking on internet. It kind of collects data that can utilized in a broad domain of applications for various uses. The various aspects can be industrial uses and home automation etc. The ALOHA protocol is re inventing its concept with respect to Internet of Things concept. This paper lays focus on successful generalization of ALOHA based on frequency slotted systems like the UNB. Time frequency random access is applied. With the combined concept of ALOHA and IoT further the performances and benefits can be harnessed to a considerable extent.

In [3] Enrico Paolini et al. threw light on the mechanism of coded slotted Aloha. This study also introduced a random access method that was based on correcting codes and cancelling out the interferences. Iterative interference subtraction is implemented to enhance the functional metric value. This paper demonstrated the successful evaluation of the ALOHA throughput based on UNB transfer of data.

In [4], F. V´azquez-Gallego et al. laid out a Performance Evaluation of Frame Slotted ALOHA with successive Interference Cancellation in Machine to Machine Networks. This is mainly done with focus on energy efficient methods where M2M machines are used considerably for the energy efficiency. It serves a doorway to a number of energy clad end devices and methods. It is shown to reduce delays and energy consumption to a great level. Over all it stands as a very efficient and feasible method to ensure great performance.

In [5], Cedomir Stefanovi´c et al. proposed their analysis and sudy on Frameless ALOHA Protocol for Wireless Networks. It was based on Slotted Aloha concept that was based on the principles of interference cancellation. The user data transmissions are kind of distributed over various slots. They proposed this method that ensures each user in an independent manner has access to the wireless network with a pre defined possibility. This is mainly done to optimize the entire slot access mechanism to reduce the lags and problems and thereby enhancing the overall system performance completely and with a greater focus on the equal access for all users. The interference is prevented and driven out as swiftly as possible which helps the system in attaining good performance and efficacy of oveall results for the proposed system.

IIII PERFORMANCE METRICS

The probability of there being zero transmission-attempts by other stations in a single timeslot is:

$$PROB_{SLOTTED} = e^{-G} \quad (1)$$

The probability of a transmission requiring exactly k attempts is (k-1 collisions and 1 success):

$$PROB_{SLOTTED}k = e^{-G}(1 - e^{-G})^{k-1} \quad (2)$$

The throughput can be computed as:

$$S_{SLOTTED} = Ge^{-G} \quad (3)$$

The maximum throughput is *1/e* frames per frame-time (reached when *G* = 1), which is approximately 0.368 frames per frame-time, or 36.8%.

The chances of false alarm increase when there is actual addition of noise in the desired spectrum. It is noteworthy that such noise effects may lead to a false interpretation that there is collision noise being injected in the signal spectrum and it is the act of eavesdropping by the adversary. This however is not true and leads to misleading and inaccurate results. The effect can be summarized as follows:
Let the threshold for collision to be present by 'T'
If $h(t) > T; Collision\ presnet$
However,
If $h(t) + n(t) > T$ holds true;
Then there is a clear chance of false alarm often computed as the probability of false alarm of collision threat.

The major performance metrics are:

Understanding the performance metrics for Slotted Aloha networks is essential for evaluating their efficiency and effectiveness. Here's a paragraph-by-paragraph breakdown of the key performance metrics:

Throughput: Throughput is a fundamental performance metric that measures the rate at which successfully transmitted packets are delivered over the network. In Slotted Aloha networks, throughput is influenced by factors such as the packet arrival rate, slot duration, and collision probability. A higher throughput indicates better network efficiency and capacity utilization.

Collision Probability: Collision probability quantifies the likelihood of multiple stations attempting to transmit in the same time slot, leading to packet collisions and potential retransmissions. In Slotted Aloha, collision probability depends on factors such as the number of active stations and the slot duration. Minimizing collision probability is essential for maximizing throughput and network efficiency.

Packet Loss Rate: Packet loss rate measures the proportion of transmitted packets that fail to reach their intended destination due to collisions or other errors. In Slotted Aloha networks, packet loss rate increases with higher collision probability and congestion levels. Minimizing packet loss rate is crucial for maintaining reliable communication and ensuring quality of service (QoS) for network applications.

Channel Utilization: Channel utilization quantifies the percentage of time slots that are successfully utilized for packet transmission over the total available time slots. In Slotted Aloha networks, channel utilization is affected by factors such as the number of active stations and the efficiency of the medium access control (MAC) protocol. Maximizing channel utilization is essential for optimizing network throughput and capacity.

Delay: Delay measures the time taken for a packet to travel from the sender to the receiver, including queuing delay, transmission delay, and propagation delay. In Slotted Aloha networks, delay increases with higher collision probability and congestion levels, impacting the responsiveness and latency of network communication. Minimizing delay is critical for real-time applications and interactive services.

Fairness: Fairness evaluates the equitable distribution of network resources among competing stations, ensuring that all users have a fair opportunity to transmit and access the network. In Slotted Aloha networks, fairness can be assessed based on criteria such as packet transmission rates and access priorities. Achieving fairness promotes cooperation and collaboration among network users, enhancing overall network performance.

Energy Efficiency: Energy efficiency measures the amount of energy consumed by network devices during packet transmission and reception. In Slotted Aloha networks, energy efficiency is influenced by factors such as the transmission power levels and the duty cycle of active stations. Improving energy efficiency is essential for prolonging the battery life of mobile devices and reducing environmental impact.

V CONCLUSION

In conclusion, understanding and optimizing these performance metrics are crucial for designing, deploying, and managing efficient Slotted Aloha networks that meet the requirements of diverse applications and users. By evaluating network performance based on these metrics, network operators and researchers can identify areas for improvement and implement targeted optimization strategies to enhance overall network performance and user experience.

REFRENCES

[1] Ana Paula Teles Ribeiro da Silva, José Marcos Câmara Brito "Analysis of Adaptive Modulation Performance in Networks with Multiple Access Slotted Aloha", IEEE 2022

[2] Claire Goursaud and Yuqi Mo, "Random Unslotted Time-Frequency ALOHA: Theory and Application to IoT UNB Networks", 2021 23rd International Conference on Telecommunications (ICT).

[3] Enrico Plaini, Gianluigi Liva Marco Chiani "Slotted Aloha:A Graph Based Method for UnCoordinated Multiple Access", IEEE Transactions On Information Theory, Vol. 61, No. 12, December 2020

[4] F. V´azquez-Gallego et al., "Performance Evaluation of Frame Slotted-ALOHA with Successive Interfrence Cancellation in Machine-to-Machine Networks", European Wireless 2018

[5] Cˇ edomir Stefanovic´, Peter Popovski, "A Random Access that Opertates as a Rateless Code IEEE Transactions On Communications, Vol. 61, No. 11, November 2017.

[6] Cedomir Stefanovi´c, et al., Frameless ALOHA Protocol for Wireless Networks", IEEE Communications Letters, Vol. 16, No. 12, December 2016.

[7] Gianluigi Liva, "Graph Based Analysis and Optimization of Contention Resolution Diversity Slotted ALOHA", IEEE Transactions On Communications, Vol. 59, No. 2, February 2015.

[8] Jun-Bong Eom et al., "Accurate Tag Estimation for Dynamic Framed-Slotted ALOHA in RFID Systems, IEEE Communications Letters, Vol. 14, No. 1, January 2014.

[9] Radha Krishna Ganti et al., "Spatial and Temporal Correlation of the Interference in ALOHA Ad Hoc Networks", IEEE Communications Letters, Vol. 13, No. 9, September 2013.

[10] M. Sarper Gokturk, Ozgur Ercetin, Ozgur Gurbuz, "Throughput Analysis of ALOHA with Cooperative Diversity", IEEE Communications Letters, Vol. 12, No. 6, June 2013.

[11] Mariam Kaynia and Nihar Jindal, "Performance of ALOHA and CSMA in Spatially Distributed Wireless Networks", in: IEEE 2012.

[12] N. Abramson "The Throughput of Packet Broadcasting Channels", IEEE Transactions on Communications, Vol 25 No 1, pp117–128, January 2011.

[13] R. Binder, ALOHAnet Protocols, ALOHA System Technical Report, College of Engineering, The University of Hawaii, September, 1974.

[14] R. Binder, W.S. Lai and M. Wilson, The ALOHAnet Menehune – Version II, ALOHA System Technical Report, College of Engineering, The University of Hawaii, September, 1974.

[15] R. Metcalfe, Xerox PARC memo, from Bob Metcalfe to Alto Aloha Distribution on Ether Acquisition, May 22, 1973.