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Enhanced Collision-Free Slotted Aloha with Priority in Contention (SAPC)

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ABSTRACT
The most simple and easy way of allocating a channel among multiple competing users is an ALOHA protocol and in this paper, a way of allocating a single shared channel among multiple competing users through slotted ALOHA without forming collisions in transmission and starvation to any station during the contention and the transmission period is proposed. The proposed Slotted ALOHA with Priority in Contention (SAPC) is better than original slotted ALOHA as the later one has collisions during the transmission period, which renders the efficiency and leads to long waiting period for stations. The enhancement in SAPC came from using priorities of station in contention slots in a slotted ALOHA (as only one station is allowed to transmit in a given time slot no collision can occur). This method provides a more convenient and efficient way of utilizing the channel among multiple users in a shared environment where collision occurrence is crucial. Also a new station requesting to access the channel is allowed to access the shared channel (assuming it has data of much higher priority) than the rest of the data accumulated by the stations in a shared channel. This condition of high priority data is serviced in this new proposed method SAPC.

General Terms
Aloha, Collision, Shared Channel, Contention, etc.

Keywords
Slotted Aloha, Pure Aloha, Framed Aloha, Collision Free, Contention Resolution, Priority, and Reservation Aloha etc.

1. INTRODUCTION
Many algorithms for allocating a channel between multiple users are known from early 1970s; Norman Abramson and his colleagues at the University of Hawaii devised a new and elegant method to solve the channel allocation problem [1] and named it ALOHA protocol. The first protocol (named PURE ALOHA) is simple and easy:

- ➔ Send data when you have.
- ➔ If there is collision, then resend the data.
- ➔ On collision wait for random amount of time and proceed again.[2]

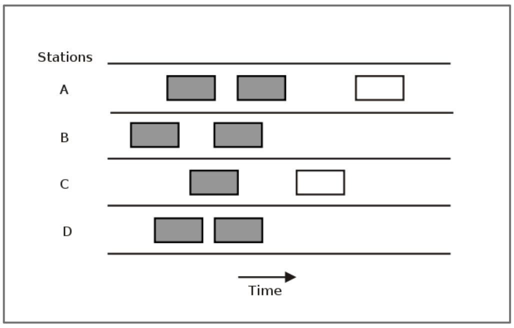

Fig 1: Pure ALOHA protocol. Box indicate frame. Shaded box indicate collided frame. [2]

Slotted ALOHA [4] and some protocols [5]-[7] based on it are an improvement to the original ALOHA protocol, which introduced discrete time slots and increased throughput (almost doubled). This resulted in a lower collision rate (almost half) and increased channel efficiency as compared to Pure Aloha.

2. ORGANIZATION OF THE PAPER
Section III describes Slotted Aloha protocol model with figure Fig2. Section IV describes the proposed technique of accessing a medium without forming collision. Section V comprises an analysis of the proposed algorithm. Section VI contains the conclusion. Section VII acknowledges the mentor for his constant guidance and section VIII provides the references.

3. PREVIOUS WORK
3.1 Slotted Aloha Protocol

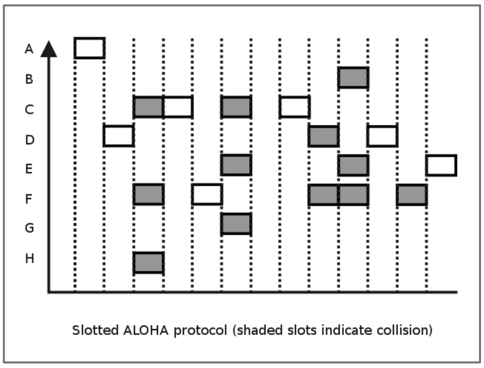

Fig 2: Slotted ALOHA protocol. Box indicate frame. Shaded box indicate frame in the same slot. [3]

Let us consider a network (wired) of *n* users that share a common channel. The working and assumptions of an ideal slotted aloha model are [8]:

Time is slotted and all packets are of equal length. Packet transmission time is one full slot.

Packets are transmitted in the next slot after they arrive.

There is no buffering i.e. a station has no more than one packet to transmit in a single slot. If that is the case the station has to buffer one or more packets for later transmission. To accommodate the no buffering concept, assume that there are infinite numbers of station and each new arrival happens on a new station.

If more than one station transmits packets in the same slot, there is collision and the receiver cannot receive the packets correctly.

Successful transmission happens only when there is exactly one packet transmitted in a slot. If no packet is transmitted in a slot, slot is idle. Packet transmission in the network is modeled by a Poisson distribution. There is immediate feedback from the receiver about the status of each transmitted packet. In case of collision, the packets are retransmitted at a later slot after a random time.

Slotted ALOHA [4] is a well-known distributed random access scheme in which the link time is divided into slots of equal duration and the users contend to access the Shared Channel (SC) by transmitting with a predefined slot-access probability. Framed ALOHA [9] is a variant in which the link time is divided into frames containing M slots, and the users contend by transmitting in a single, randomly chosen slot of the frame. Both in slotted and framed ALOHA, only the slots containing a single user's transmission (i.e., singleton slots) are useful and the corresponding transmission is successfully resolved, while the slots containing no user transmission (i.e., idle slots) or multiple user transmissions (i.e., collision slots) are wasted.

4. PROPOSED TECHNIQUE

4.1 Slotted ALOHA with Priority in Contention (SAPC)

Assumptions:

- Time is slotted and slots are synchronized.
- A buffer which stores state of current requests from station {Current Request Buffer (CRB)} and previously serviced station {Previous request Buffer (PRB)}.
- There are no frequent errors or loss during transmission of frames so that there is no need to retransmit the frames.
- User may or may not have packets to send in each slot.
- Each user has to contend with others to acquire the channel for transmitting its data.

A global Contention Queue (CQ) is used to store the requests from all the stations.

Assume that there are **X** users in the system, out of which a random subset of **N** *active* users are contending for access to the Shared Channel (SC). The start and the end of the contention period are denoted through a beacon sent by the SC. The contention period is divided into slots of equal duration, and the users are synchronized on a slot basis. The length of the contention period is M slots; M is not determined a priori and gets assigned its value dynamically, when the number of contending users is known. Within the contention, each active user accesses the medium and transmits packets on a slot basis by using identical slot-access probability pa [10] p_a=1/N. This value p_a is broadcast by the SC via beacon at the start of the contention period and is determined based on the estimation of **N** available at SC. We will assume at first that SC knows perfectly **N** and discuss the consequences of violating that assumption later. The contention period ends when the SC sends a new beacon.

Before any station can acquire shared channel for transmission, contention among all stations having data to send occurs. Each station having data frame to send, request a slot by placing a request packet in the global contention queue (CQ). This queue is resolved on the basis of FCFS (first come first serve) and transmission parameters as, processing delays, queuing delays, transmission delays, propagation delays, round trip delays which govern toward the selection of a station from the rest conflicting stations. The result of this contention is broadcasted to all the communicating stations and each station refresh its memory which contain details about the ongoing transmission and the queues viz. CQ, PQ, CRB, PRB. This method results in allocation of shared channel to a single station for a particular period of time (Equivalent to frame length divided by bit rate). No other station can have access to the shared channel when a station is using it for transmitting its frame. This restriction results in no collision in a shared medium when *N* users are competing for the channel.

4.2 System model of SAPC

ABCDEFGH are the 8 stations considered and only few of the have to transmit data first.

*4.2.1 **CASE I** – Only N stations are known.*

1) Let stations (ABDE) each has a frame to send in the shared medium, then each put a request for channel acquisition in the Contention Queue (CQ). The CQ keeps the record of the stations contending at a given time period. Number of stations in the CQ is the highest amount of priority (here it is 4 as 4 stations are present in the CQ) that can be assigned to the nodes at that time. Apart from CQ a Priority Queue (PQ) is also maintained holding the priority of each station. Each station in the CQ is assigned a number equal to the number of stations in CQ to the respective stations in PQ. The very first conflict is resolved by the various parameters specified as FCFS and delays (as processing delays, queuing delays, transmission delay, propagation delay) associated with each station. Then the station is allowed to transmit its frame in the required slot.
2) When a station completes its transmission, then, from the PQ the priority assigned to that station is subtracted by 1 and PQ is updated. If the same station has more data to send then it waits for a time till its priority becomes higher than others. Now, the Current Request Buffer (CRB) is scanned for transmission request of other stations having higher priority. If priorities of the requests in the CRB are same then it's solved in the same manner as done previously in start. This is done till the requests in CRB empties or no new station request for transmission, having its

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priority higher than in the PQ. Another buffer, Previous Request Buffer (PRB) is used to store the status of station which is recently serviced.

3) When the priority in the PQ for a station goes to 0 (zero) and still it has data to transmit and it keeps requesting for slots, then that station is serviced first and a priority one less than the highest priority in the PQ is assigned to that station if no other station requested. If another station having priority higher than this station (currently having 0 priority) requests at that time then the higher priority station is serviced. The station having priority 0 is serviced in the next slot.

4) The station with priority 0 as in the previous step has associated with it a timer that goes off after predefined slot intervals. This timer counteracts with the effect of starving the station with lowest priority.

4.2.2 **CASE II** - *when a new station request for transmission.*

1) If a station requests for channel to transmit data apart from the station being serviced in the queues, then a priority higher in the PQ is assigned to the respective position of the new station in PQ. Now, if no other station has requested for channel then the new station is allowed access to the shared channel. But, as the assigned priority is higher than the priority of the contending stations in the PQ. The newly requested station is made to wait for one slot till the old station completes transmission and then the new station is allowed to access the shared channel. This is done so as to avoid starvation to any station as whenever a new station arrives it will always have priority higher or equal to the older contending stations.

2) If the newly assigned priority is similar to the priority of another station requesting channel. The PRB is scanned, if the older station is serviced just before the new station requested for the shared channel, then the new channel is allowed to access the channel to transmit the data. This is done so as to keep the waiting time for each station low and approximately equal to one frame length.

4.3 Proposed Method SAPC

! – Represents the station requesting access to the shared channel.

CASE I

	A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	
1)	*4!*	*4!*	-	*4!*	*4!*	-	-	-	*A, B, D, E requesting to Transmit. See Fig.3*
	4!	*3*	-	*4!*	*4!*	-	-	-	*B was allowed to transmit based on Transmission (Tx) factors (delays, FCFS) & CRB is scanned and contains A, D, E. PRB now contain B.*
2)	*4!*	*3*	-	*3*	*4!*	-	-	-	*D transmits, A&E are left in CRB of which A is choosen to transmit based on Tx factors as B was selected. PRB contain B, D.*
	3	*3*	-	*3*	*4!*	-	-	-	*A transmits and then E is left in CRB so E is serviced. PRB contain B, D, A.*
	3	*3*	-	*3*	*3*	-	-	-	*E transmits. PRB contain B, D, A, E. See Fig.4*
	3	*3*	-	*3!*	*3*	-	-	-	*D requests to transmit.*
	3	*3*	-	*2*	*3*	-	-	-	*D transmits.*
	3	*3*	-	*2!*	*3!*	-	-	-	*E will transmit as priority is Greater than D.*
	3	*3*	-	*2!*	*2*	-	-	-	*E transmits and CRB is scanned.*
	3	*3*	-	*2!*	*2!*	-	-	-	*E requests again to transmit.*
	3	*3*	-	*1*	*2!*	-	-	-	*PRB is scanned as E was Serviced last, so D is allowed to transmit.*
	3	*3*	-	*1*	*1*	-	-	-	*CRB is scanned & E transmits.*
	3	*3*	-	*1!*	*1*	-	-	-	*D request to transmit.*
	3	*3*	-	*0*	*1*	-	-	-	*D allowed to transmit.*

3)	*3*	*3*	-	*0!*	*1*	-	-	-	*D again request to transmit but since priority is zero so first serviced and then assigned a new priority equal to highest priority-1 in PQ (i.e.3-1= 2).*
	3	*3*	-	*2*	*1*	-	-	-	*D transmitted. Priority of D is set to 2.*
	3	*3!*	-	*0!*	*1*	-	-	-	*B and D both request to transmit, PRB is scanned if B's entry is there then D is allowed or vice-versa.*
4)	*3!*	*3*	-	*0!*	*1*	-	-	-	*Both A & D request. Suppose no entry for A is found in PRB. So A is allowed to transmit. Timer for D with 2 slot starts.*
	2	*3!*	-	*0!*	*1*	-	-	-	*B & A (Old request) request to transmit. B with higher priority is allowed to transmit. Timer associated with D goes off and it transmit in next slot irrespective of other stations request.*
	2	*2*	-	*1*	*1*	-	-	-	*A new priority equal to highest priority-1 in PQ (i.e.2-1= 1) is assigned to D after transmission.*

CASE II

1) New station requests in between servicing old stations.

A	***B***	***C***	***D***	***E***	***F***	***G***	***H***	
4	*3*	-	*2*	*3*	-	*!*	-	*G now request to transmit.*
4	*3*	-	*2*	*3*	-	*4!*	-	*G is given a priority equal to the highest priority in the PQ and waits for one slot. This is done so to avoid starvation of old Stations.*
4	*3*	-	*2*	*3*	-	*3*	-	*If no one request then G is serviced in this slot.*

2) *If a new and old station request simultaneously*

A	***B***	***C***	***D***	***E***	***F***	***G***	***H***	
4!	*3*	-	*2*	*3*	-	*4!*	-	*If priority of new station is same as that of an old requesting station then this contention is resolved in the same manner as done in Starting on Tx factors and anyone (A or G) can transmit.*
4	*3*	-	*2!*	*3*	-	*!*	-	*G & D both requests*
4	*3*	-	*2!*	*3*	-	*4!*	-	*PRB is scanned if there is a last entry for D Then G is allowed to transmit*
4	*3*	-	*2!*	*3*	-	*3*	-	*G transmitted*
4	*3*	-	*1*	*3*	-	*4!*	-	*If no entry in PRB then CRB request is serviced first and G waits for next slot.*

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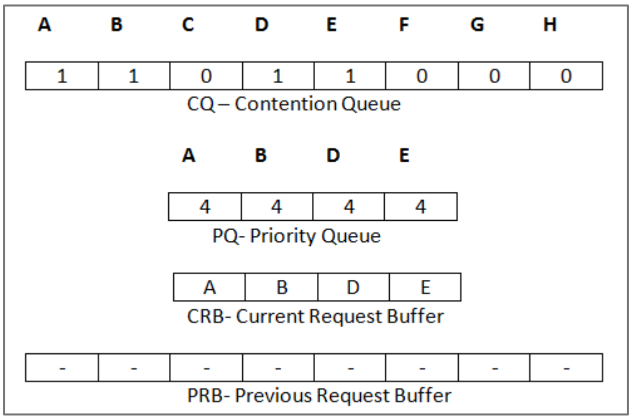

Fig 3: Shows the state of Queues at Starting CASE I (1).

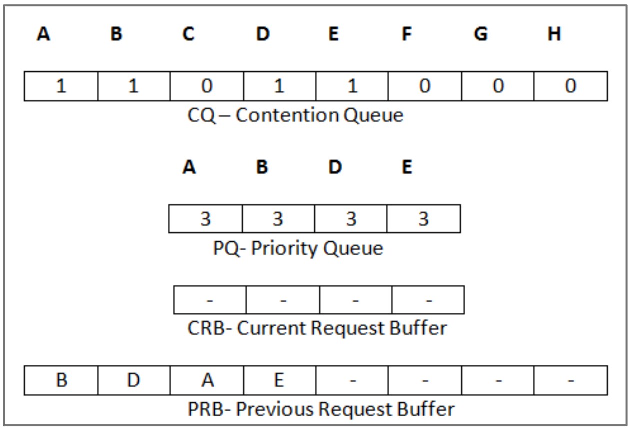

Fig 4: Shows the Queues after the CASE I (2).

5. ANALYSIS

The proposed method of allocating a channel in a multi user environment without sensing channel is efficient as compared to the basic slotted Aloha protocol where the users are given a slot for transmitting the data. Also, in the slotted aloha protocol if one or more user tries to send packets in the given slot, then collisions occur which results in lower throughput and more delays. Hence, leading to low channel utilization. The main difference between Slotted ALOHA and SAPC is that with Slotted ALOHA any slot is available for utilization without regards to prior usage. Variations [5]-[7] are also better than the basic slotted Aloha protocol. The proposed protocol SAPC is much similar to Reservation Aloha (R-Aloha) where reservations are made to the stations who want to transmit. The improvements with Reservation ALOHA are markedly shorter delays and ability to efficiently support higher levels of utilization. As a contrast of efficiency, simulations have shown that Reservation ALOHA exhibits less delay at 80% utilization than Slotted ALOHA at 20–36% utilization [11] .A drawback of R-Aloha is that the reservation of slot is for the period of time till the station gives up which leads to long waiting time for other stations [12] thus making it inefficient for networks with large number of stations where the station may or may not always have data to send. In SAPC the slots are not reserved a priori, they are allocated to the stations after the contention. Under SAPC contention-based reservation schema, the slot is temporarily considered "owned" by the station that successfully used it. Additionally, SAPC simply stops sending data once the station has completed its transmission. As a rule, idle slots are considered available to all stations that may then implicitly reserve (utilize) the slot on a contention basis.

5.1 Figurative Analysis

Here, proposed method is analyzed with the existing aloha systems as discussed previously in this paper. The comparison is shown in both tabular and diagrammatic form. Consider there are 3 stations at present A, B and C each having 3, 4 and 2 data frames to send respectively. These stations have continuous data frames aligned in buffer to transmit. Two conditions are considered for comparison between proposed aloha model SAPC and aloha variants.

1. Time (t1) it takes for one station to completely transmit its data.
2. Time (t2) between the two stations sending their first frame, where one station ends and second starts.

5.1.1 Slotted Aloha

In Fig 5, each station transmits data whenever they want. This randomness in transmission leads to collisions and loss of data which, results in retransmission of data till the data is sent successfully.

For example, station C has 2 data frames to send. It starts at 0ms and completed at 180ms. So, t1= (180-0)ms = 180ms.

Next consider two stations A and B, first frame of A (A1) starts at 100ms and of B (B1) starts at 20ms. Therefore, t2 = (100-40)ms = 60ms.

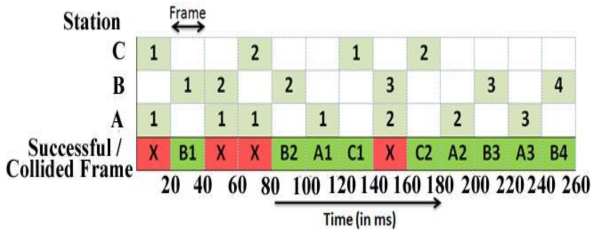

Fig 5: Shows Packet Transmission of 3 stations for Slotted Aloha.

5.1.2 R-Aloha

In Fig 6, each station transmits data according to the slots reserved. This reservation of slots for each station is in continuous slots till the station gives up for transmission which, results in no collision during the transmission.

Here, time taken by station C to completely transmit t1= (180-140)ms= 40ms. Time between first frame of station A & B t2= (60-20)ms= 40ms.

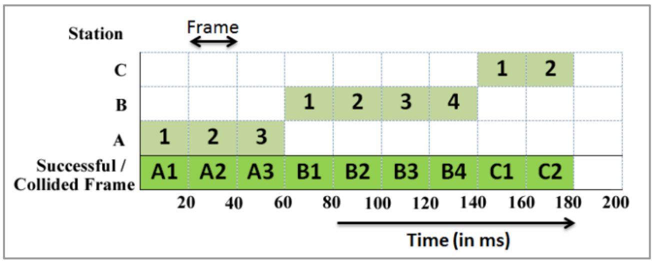

Fig 6: Shows Packet Transmission of 3 stations for Reservation-Aloha (R-Aloha).

5.1.3 Proposed SAPC

In Fig 7, each station is allowed to transmit data according to the contention resolution parameters defined.

In this time taken by station C to transmit 2 frames, t1= (120-40)ms = 80ms. Time between two frames for station A & B t2= (20-20)ms= 0ms.

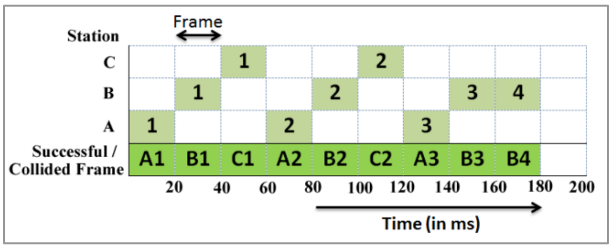

Fig 7: Shows Packet Transmission of 3 stations for proposed SAPC.

The result obtained after comparison of all the three aloha is shown in Table1. It can be analyzed from the results that for a station the two parameters (t1, t2) need to be minimum in some situation or the other. As for all the methods t1 is minimum in R-Aloha which signifies that the least amount of delay is introduced in between data transmission of a particular station. Similarly, t2 defines the amount of delay introduced in between two stations sending their first frame. The parameter t2 is low in proposed SAPC method, which indicates that it is most suitable for situations in which another station needs to transmit data without having to wait for long.

Table 1.Comparison of result between different aloha protocols.

Method / Parameter	S-ALOHA	R-ALOHA	SAPC
T1(in ms)	180	40	80
T2(in ms)	60	40	0

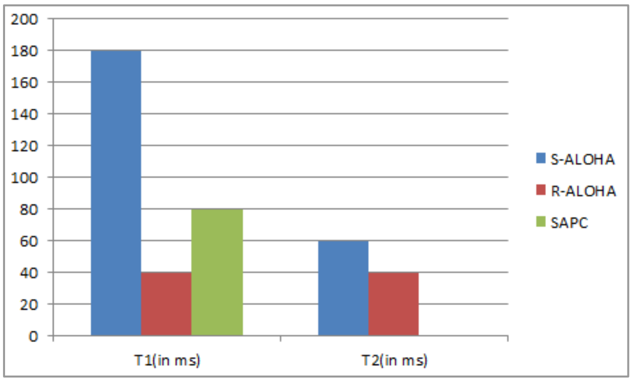

Fig 8: Performance comparison of proposed and existing method.

Table 2.Comparison among SAPC, Slotted Aloha and R-Aloha

Metric	SAPC	Slotted Aloha	R-Aloha
Priority of Data	Data with Priority is Allowed to transmit first	No Priority associated DATA	No Priority Associated with DATA
Medium Access	Contention Based	Random Access	Reserved Slot Access
New Station Arrival	No waiting time for new stations	No waiting	Have to wait for long till Old one transmits
Data Collisions	No Collision	Collision occurs frequently	No collision
Transmission Type	One Station in each Slot	Random transmission	One station till end of data

6. CONCLUSION

It is concluded that the proposed method SAPC gives a chance for priority data to be transmitted before the data in the queues ensuring no collision for transmitting stations. It also ensures that a station must not wait for so long (within boundary waiting time) to transmit when in a queue, hence neglecting the situation of starvation to any station. There is further scope of work in this field to speed up the process of checking buffers and queues, which can improve the waiting time of transmitting stations. Various technique of Artificial Neural Network (ANN) can be incorporated to implement, enhance and make it a smart resource allocator to distribute a single shared medium among a number of stations.

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