UNIT - 5

THE LINK LAYER: LINKS, ACCESS NETWORKS and LANs

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1) The Services provided by the link layer:

1) Framing:

* Almost all link-layer protocols encapsulate each network-layer datagram within a link-layer frame before transmission over the link.

* The structure of the frame is specified by the link layer.

2) Link access:

* A medium access control (MAC) protocol specifies the rules by which a frame is transmitted onto the link.

* For point-to point links that have a single sender at one end of the link and a single receiver at the other end of the link, the MAC protocol is simple. The sender can send a frame whenever the link is idle.

* The more interesting case is when multiple nodes share a single broadcast link - the so called multiple access problem.

3) Reliable Delivery:

* When a link layer protocol provides reliable delivery service, it guarantees to move each network-layer datagram across the link without

error.

* A link layer reliable delivery service can be achieved with acknowledgements and transmissions.

4) Error detection and correction:

* Errors are introduced by signal attenuation and electromagnetic noise.

* Many link-layer protocols provide a mechanism to detect such bit errors.

* This is done by having the transmitting node include error detection bits in the frame & having the receiving node performs an error check.

* Receiver identifies and corrects bit error(s) without resorting to retransmission

5) Flow control:

* Pacing b/n adjacent sending and receiving nodes

6) Half duplex and full duplex:

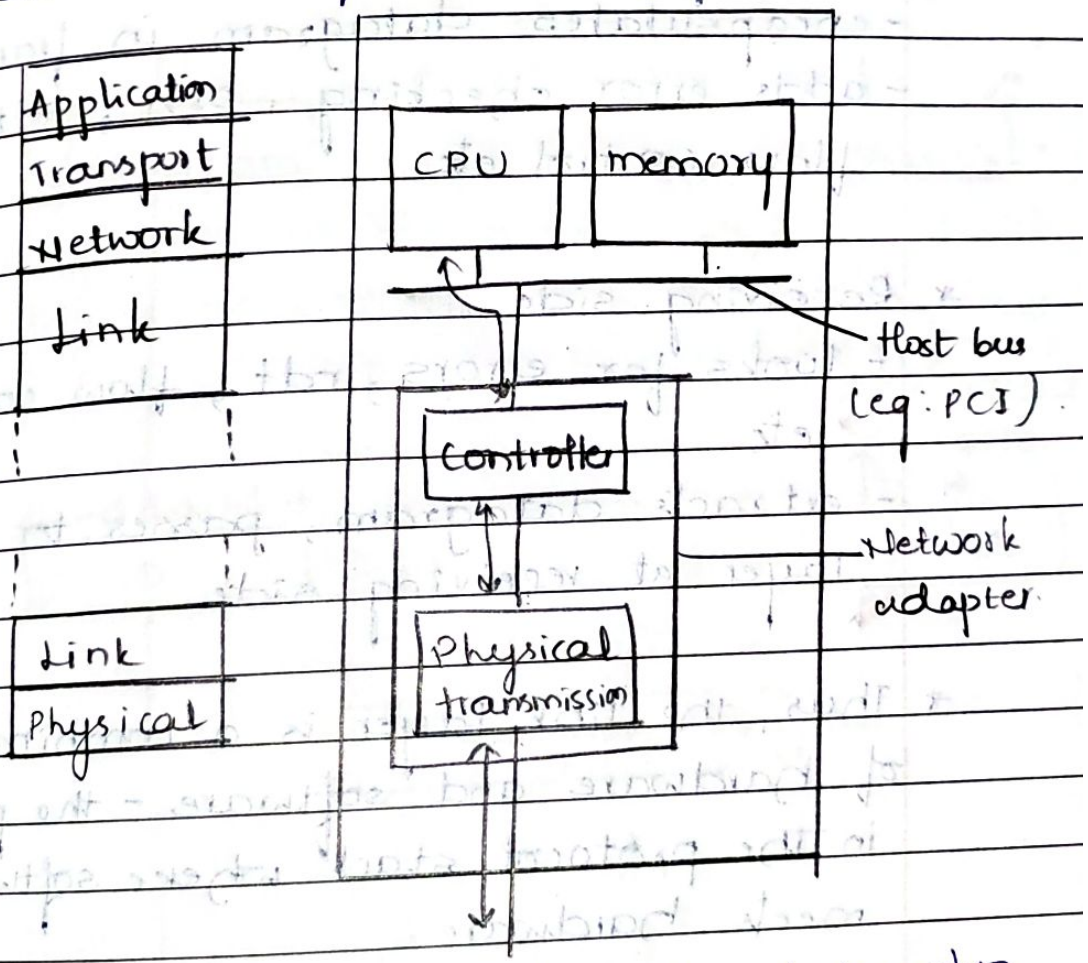
* With half duplex, nodes at both ends of link can transmit, but not at the same time.

* Full duplex protocol allows an application program to send and receive information concurrently.

2) Where is the link layer implemented?

* It is implemented in each and every host.

* The link layer is implemented in a network adapter, also sometimes known as a Network Interface card (NIC).



Network Adapter: its relationship to other host components & to protocol stack functionality.

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* Figure shows a network adapter attaching to a host's bus (eg: PCI), where it looks much like any other I/O device to other host components.

* Figure also shows that while most of the link layer is implemented in hardware, part of the link layer is implemented in software that runs on the host's CPU.

* Sending side:
- encapsulates datagram in frame
- adds error checking, bits, rdt, flow control etc.

* Receiving side:
- looks for errors, rdt, flow control etc.
- extracts datagram, passes to upper layer at receiving side.

* Thus, the link layer is a combination of hardware and software - the place in the protocol stack where software meets hardware.

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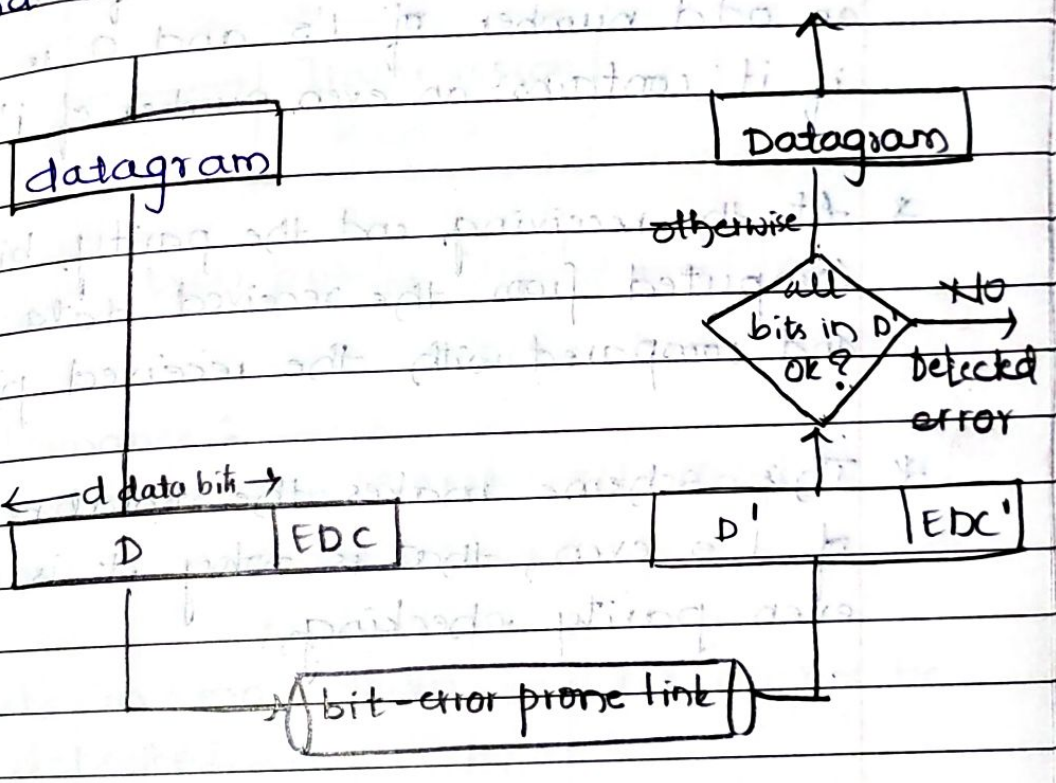
3) Error detection :

* EDC - Error detection and correction bits (redundancy)

* D - Data protected by error checking, may include header fields.

* Error detection is not 100% reliable.
- Protocol may miss some errors, but rarely
- larger EDC field yields better detection and correction



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4) Parity checks :

* In this technique, a redundant bit called parity bit, is appended to every data unit so that the number of 1s in the unit including the parity becomes even.

* Block of data from the source are subjected to a check bit or Parity bit generator form, where a parity of 1 is added to the block if it contains an odd number of 1's and 0 is added if it contains an even number of 1's.

* At the receiving end the parity bit is computed from the received data bits and compared with the received parity bit.

* This scheme makes the total number of 1's even, that is why it is called even parity checking.

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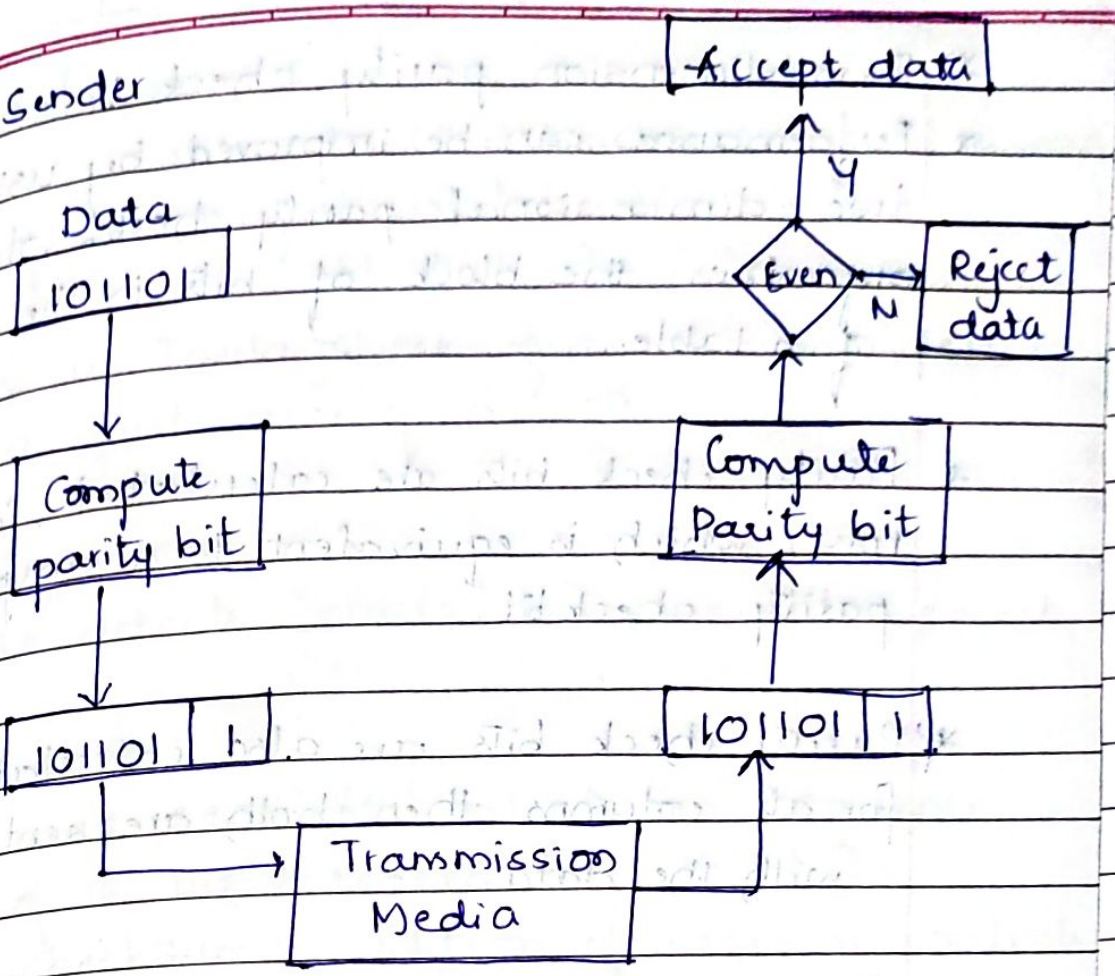
Receiver



Even parity checking sum.

Performance:

* A receiver can detect all single bit errors in each code word.

* Errors in more than ~~one~~ bit cannot be detected.

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* Two-dimension parity check:
* Performance can be improved by using two-dimensional parity check, which organizes the block of bits in the form of a table.
* Parity check bits are calculated for each row, which is equivalent to a simple parity check bit.
* Parity check bits are also calculated for all columns then both are sent along with the data.
* At the receiving end these are compared with the parity bits calculated on the received data.

Original	10110111	10101011	01011010	11010101
Column parities	10011011	1		Row parities
	10101011	1		
	01011010	0		
	11010101	1		

Data to be sent	10110111 | 10101011 | 01011010 | 11010101 | 10011111

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Performance:
* 2-D Parity checking increases the likelihood of detecting burst errors
* 2-D Parity check of n-bits can detect a burst error of n-bits

5) Checksums:
* It detects "errors" in transmitted packet

* Sender:
- treat segment contents as sequence of 16 bit integers.
- checksum: addition of segment contents
- Sender puts checksum value into UDP checksum field.

* Receiver:
- Compute checksum of received segment.
- check if computed checksum equals checksum field value:
  NO - error detected
  YES - No error detected.

* Performance:
- It detects all errors involving an odd no. of bits.
- It also detects most errors involving even number of bits.

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```
  1 0 1 1 0 0 1 1
  1 0 1 0 1 0 1 1
 (1)0 1 0 1 1 1 1 0
                 1
 ---------------
  0 1 0 1 1 1 1 1
  0 1 0 1 1 0 1 0
 ---------------
  1 0 1 1 1 0 0 1
  1 1 0 1 0 1 0 1
 ---------------
 (1)1 0 0 0 1 1 1 0
                 1
 ---------------
sum:  1 0 0 0 1 1 1 1
complement: 0 1 1 1 0 0 0 0
```

Received data:

```
  1 0 1 1 0 0 1 1
  1 0 1 0 1 0 1 1
 ---------------
 (1)0 1 0 1 1 1 1 0
                 1
 ---------------
  0 1 0 1 1 1 1 1
  0 1 0 1 1 0 1 0
 ---------------
  1 0 1 1 1 0 0 1
  1 1 0 1 0 1 0 1
 ---------------
 (1)1 0 0 0 1 1 1 0
                 1
 ---------------
  1 0 0 0 1 1 1 1
  0 1 1 1 0 0 0 0
 ---------------
sum:  1 1 1 1 1 1 1 1
complement: 0 0 0 0 0 0 0 0
```

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6) Cyclic Redundancy checks :

* CRC is the most powerful and easy to implement technique.

* CRC is based on binary division.

* In CRC, a sequence of redundant bits are appended to the end of data unit so that the resulting data unit becomes exactly divisible by second, paradetermined binary number.

* At the destination, the incoming data unit is divided by the same number.

* At this step there is no remainder, the data unit is assumed to be correct and is therefore accepted.

* A remainder indicates that the data unit has been changed in transit & therefore must be rejected.

* The binary no. which is (r+1) bit in length, can also be considered as the coefficients of a polynomial called Generator polynomial

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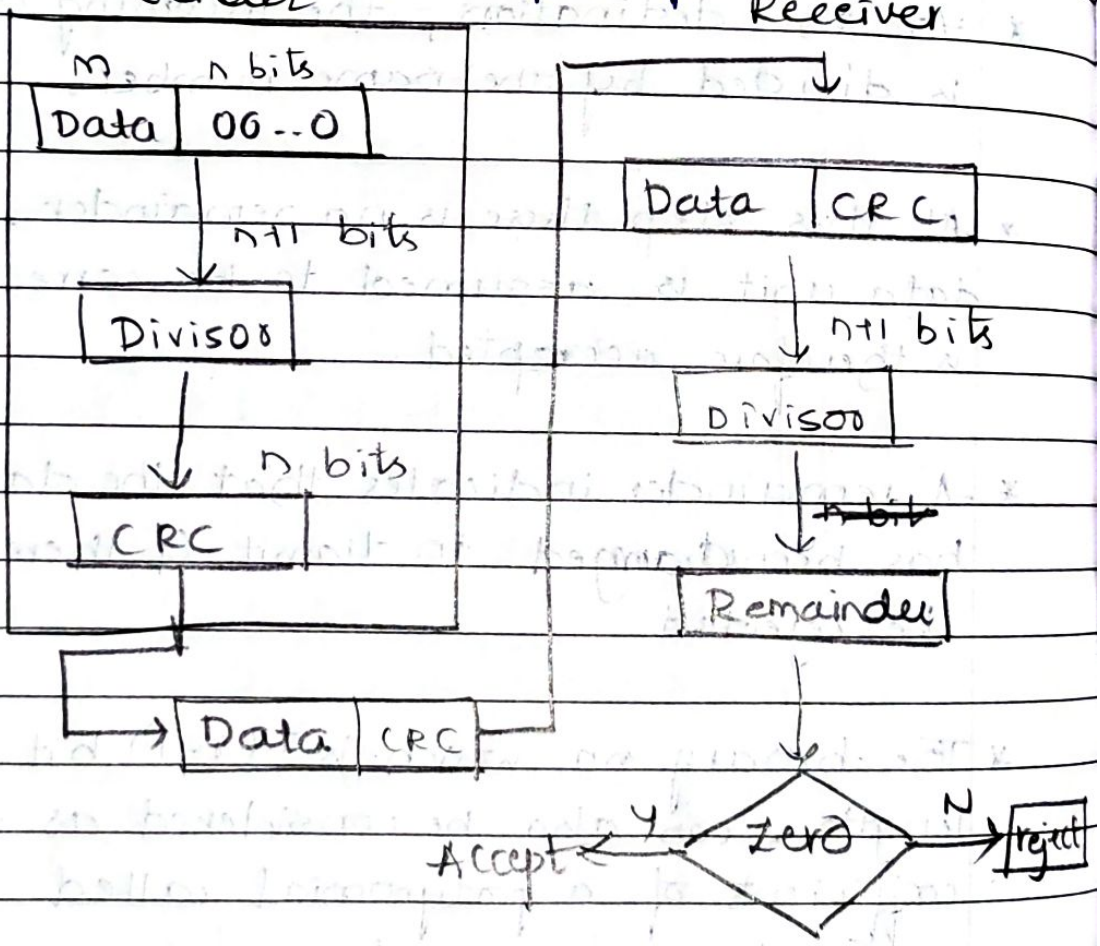
Performance:

* CRC is very effective in error detection

* If the divisor is chosen according to the previously mentioned rules, its performance can be summarized as follows.
  - CRC can detect all single-bit errors
  - CRC can detect all double-bit errors
  - CRC can detect any odd-number of errors
  - CRC can detect all burst errors of less than the degree of polynomial



Basic scheme for CRC

same - 0
diff - 1

A	B	A XOR B
0	0	0
0	1	1
1	0	1
1	1	0

```
          1 1 1 1 0 1
      ____________________
1101 ) 1 0 0 1 0 0 0 0 0
       1 1 0 1
       -------
       0 1 0 0 0
         1 1 0 1
         -------
         0 1 0 1 0
           1 1 0 1
           -------
           0 1 1 1 0
             1 1 0 1
             -------
             0 0 1 1 0
               0 0 0 0
               -------
               0 1 1 0 0
                 1 1 0 1
                 -------
                 0 0 1
```

divisor ← 1101

l = 4

l - 1 = 3

3 0's are appended to the message

Remainder

CRC : 001

Data transmitted : 100100001

frame · CRC

$x^7 + x^5 + x^2 + x + 1$

$x^6 \quad x^4 \quad x^3$

↓ ↓ ↓

1 0 1 0 0 1 1 1

2) Frame : 1 1 0 1 0 1 1 0 1 1

Generator : 1 0 0 1 1

Message after appending 4 zero bits :

1 1 0 1 0 1 1 0 1 1 0 0 0 0

1 1 0 0 0 0 1 0 1 0

1 0 0 1 1) 1 1 0 1 0 1 1 0 1 1 0 0 0 0

1 0 0 1 1

0 1 0 0 1 1

1 0 0 1 1

0 0 0 0 0 1

0 0 0 0 0 0

0 0 0 0 1 0

0 0 0 0 0

0 0 1 0 1

0 0 0 0 0

0 1 0 1 1

0 0 0 0 0

1 0 1 1 0

1 0 0 1 1

0 0 1 0 1 0

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1 0 1 0 0

1 0 0 1 1

0 1 1 1 0

0 0 0 0 0

1 1 0 0 0 0 1 0 1 0 1 1 1 0

1 1 1 0

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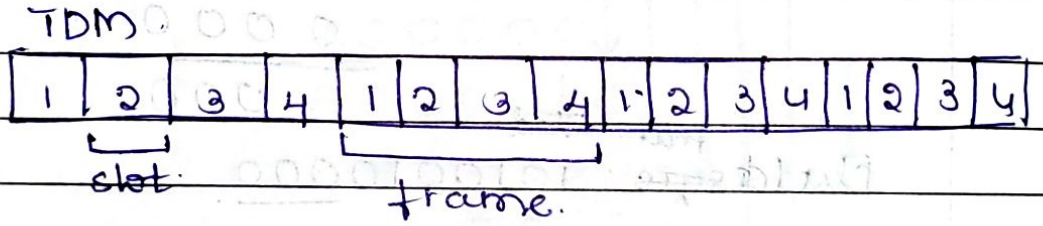
f) TDMA : Time Division Multiple Access

* Suppose the channel supports N nodes & that the transmission rate of the channel is R bps.

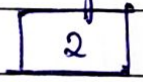
* TDM devides time into time frames & further devides each time frame into N time slots

* Each time slot is then assigned to one of the N nodes.

* Typically, slot sizes are chosen so that a single packet can be transmitted during a slot time.



key:



All slots labeled "2" are dedicated to a specific sender receiver pair.

* TDM is attractive because it eliminates collisions and perfectly fair.

* 2 Drawbacks :

1) A node is limited to an avg. rate of R/N bps even when it is the only node with

packets to send.

2) A node must always wait for its turn in the transmission sequence again, even when it is the only node with a frame to send.

8) FDMA : Frequency Division Multiple Access

* FDMA devides the R bps channel into different frequencies (each with a bandwidth of R/N) & assigns each frequency to one of the N nodes.

* FDM thus creates N smaller channels of R/N bps out of the single, larger R bps channel.

* FDM shares both advantages & disadva-ntages of TDM.

* It avoids collisions & divides the bandwidth fairly among the N nodes.

* FDM also shares a principal disadvantages with TDM - A node is limited to a bandwidth of R/N, even when it is the only node with packets to send.

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9) Pure ALOHA :-

* Pure ALOHA allows users to transmit whenever they have data to be sent.

* Senders wait to see if a collision occured.

* If a collission occurs, each station involved waits a random amount of time then tries again.

* Systems in which multiple users share a common channel in a way that can lead to conflicts are widely known as contention systems.

* Whenever 2 frames try to occupy the channel at the same time, there will be a collision.

* If the first bit of a new frame overlaps with just the last bit of a frame almost finished, both frames will be totally destroyed & both will have to be transmitted later.

* The maximum throughput occurs at $G = 0.5$ with $S = 1/2e$, which is about 0.184.

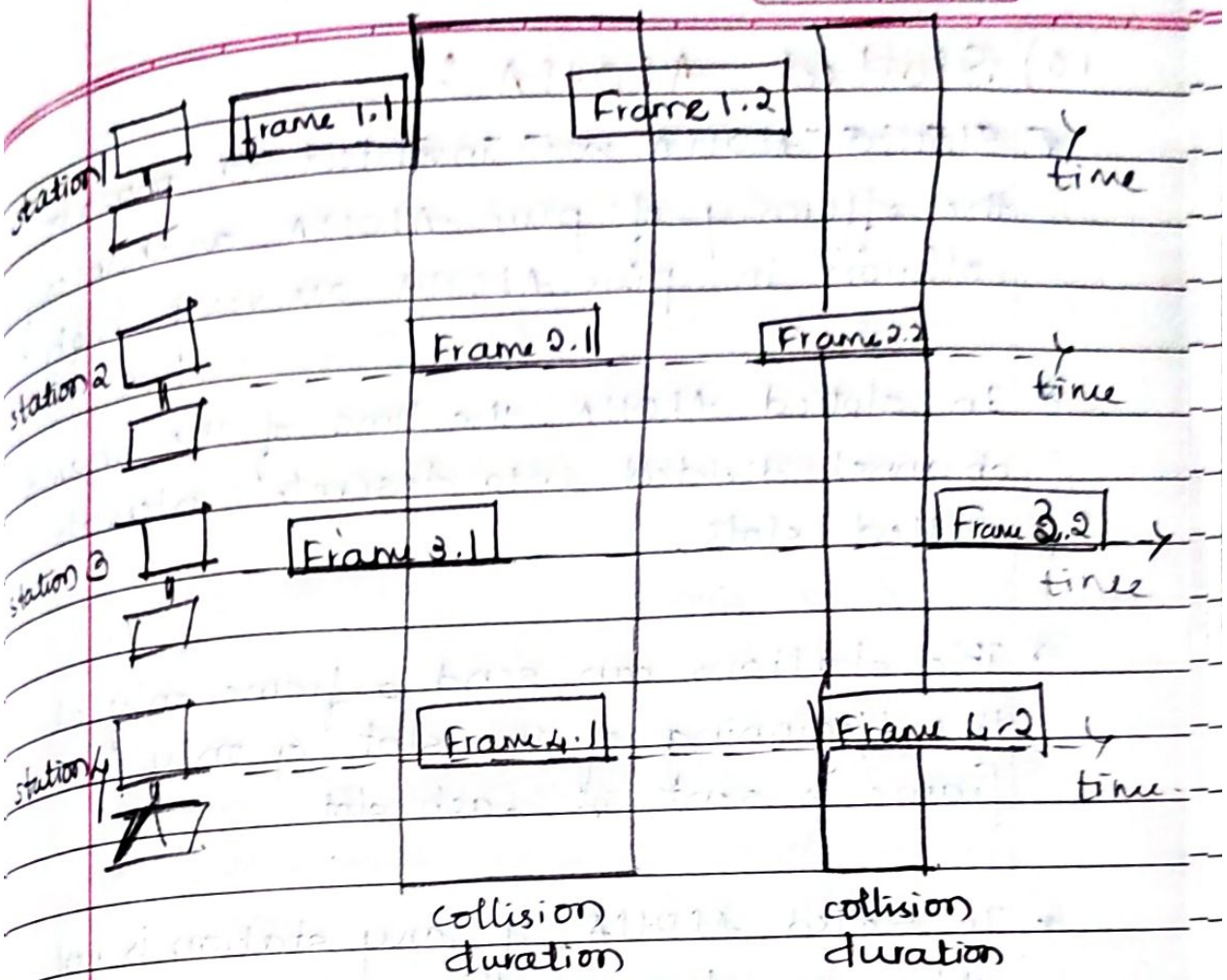


Figure: In pure ALOHA, frames are transmitted at completely arbitrary times.

* The probability that k frames are generated during a given frame time is given by the Poisson Distribution:

$$P_r[k] = \frac{G^k e^{-G}}{k!}$$

where, G - offered load P_0 -
k - frames.

* The throughput S, $S = GP_0$.

G - offered load, P_0 - the probability that a frame doesn't suffer a collision.

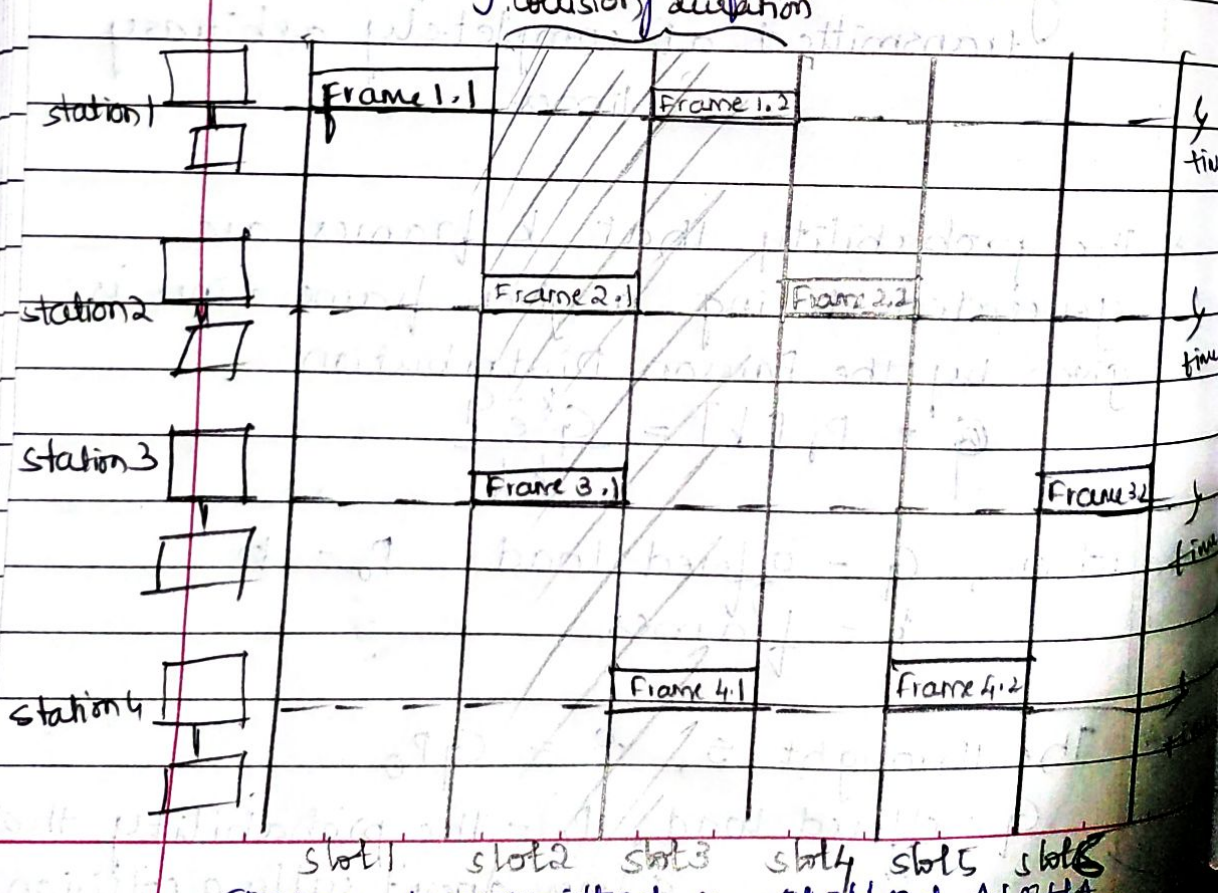
10) Slotted ALOHA :

* Slotted ALOHA was invented to impr the efficiency of pure ALOHA as chan collision in pure ALOHA are very hi

* In slotted ALOHA, the time of the sha channel divided into descrete interval called slots.

* The stations can send a frame only a the beginning of the slot & only one frame is sent in each slot.

* In slotted ALOHA, if any station is not able to place the frame onto the chan at the beginning of the slot.



Frames transmitted in ~~SLOTTED~~ ALOHA

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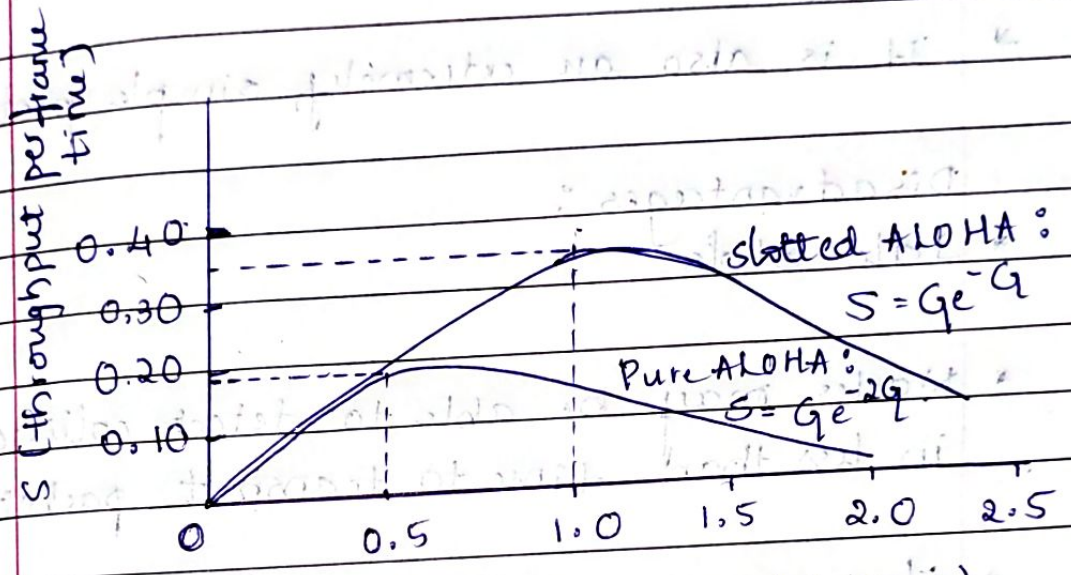
* What is the efficiency of an ALOHA channel?

- Pure ALOHA → $S = Ge^{-2G}$
- Slotted ALOHA → $S = Ge^{-G}$



Throughput v/s offered traffic for ALOHA systems.

* Maximum for pure ALOHA occurs at $G = 0.5$ for which $S = 1/2e = 0.184$ which means the rate of successful transmission is $\approx$ 18.4 %.

* For slotted ALOHA, $G = 1$, $S = 1/2e$
$= 0.368$ 36.8 %.

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Advantages :

* A single active node can continuously transmit at full rate of channel.
* Slotted ALOHA is also decentralized.
* It is also an extremely simple protocol.

Disadvantages :

* Idle slots.
* Nodes may be able to detect collision in less than time to transmit packet.
* Clock synchronization.