## HY-335 Computer Networks Link Layer Workshop $15^{\text {th }}$ Dec 2023

## Multiple Access Links and Protocols

## Slotted ALOHA

In the following 3-node transmission diagram, what is the probability of transmission $\mathbf{p}$ (assume it's same for all 3 nodes)?
From the diagram below, can we roughly estimate the value of $\boldsymbol{p}$ ?


1 $\square$

$\square$


$$
\Rightarrow p=10 / 27=\sim 0.37
$$

## Slotted ALOHA

What is the efficiency of this protocol?
Formula for slotted ALOHA is $E(p)=N p(1-p)^{N-1}$.


$$
\left.\begin{array}{rlrl}
p=0: E(0)=15 \times 0 \times(1-0)^{15-1} & p=0.3: E(0.3) & =15 \times 0.3 \times(1-0.3)^{15-1} \\
& =0 & & =0.031
\end{array}\right)
$$

But why is the efficiency formula $E(N, p)=N^{*} p(1-p)^{N-1}$

## Pure ALOHA

$>$ Suppose four active nodes—nodes A, B, C and D—are competing for access to a channel using slotted ALOHA.
$>$ Assume each node has an infinite number of packets to send.
$>$ Each node attempts to transmit in each slot with probability $p$.
$>$ The first slot is numbered slot 1 , the second slot is numbered slot 2 , and so On.
a. What is the probability that node A succeeds for the first time in slot 5 ?
b. What is the probability that some node (either $\mathrm{A}, \mathrm{B}, \mathrm{C}$ or D ) succeeds in slot 4?

## Pure ALOHA

a. What is the probability that node A succeeds for the first time in slot 5 ?
$P(A$ transmits in a slot $)=p^{*}(1-p)^{3}$,
so $P(A$ does not transmit in a slot $)=1-p^{*}(1-p)^{3}$

$$
\begin{aligned}
& P(A \text { transmits in slot } 5)=\frac{\left(1-p(1-p)^{3}\right)^{4}}{\text { No transmission }} \\
& \text { before slot } 5
\end{aligned} \frac{p(1-p)^{3}}{\text { Transmission }} \begin{aligned}
& \text { at slot } 5
\end{aligned}
$$

b. What is the probability that some node (either $A, B, C$ or $D$ ) succeeds in slot 4?

Similarly, $P($ any transmits in slot 4$)=4 p(1-p)^{3}$

## CSMA/CD (ETHERNET)

In CSMA/CD, after the 5th collision, what is the probability that a node chooses $K=4$ ? Does the result $K=4$ correspond to a delay of how many seconds on a 10 Mbps Ethernet?

## ETHERNET

## Solution:

After the 5th collision ( $n=5$ ), the range from which $K$ is chosen is [ $\left.0,1,2, \ldots, 2^{5}-1\right]$, or $[0,1,2, \ldots, 31]$ (exponential backoff).

The range contains 32 values, only one of them is 4 so $P(K=4)=1 / 32$.

Also, the result K=4 corresponds to a delay of K x $512=2048$ bit-times.
Given a 10 Mbps Ethernet, the delay will be equal to 2048/(10*106), the result of which is delay $=204.8 \boldsymbol{\mu}$.

## CSMA/CD (ETHERNET)

Suppose nodes $A$ and $B$ are on the same 10 Mbps broadcast channel, and the propagation delay between the two nodes is 245 bit times.

Suppose $A$ and $B$ begin transmission at $t_{0}=0$ bit times. They both detect collisions at $t_{1}=254$ bit times. Suppose $K_{A}=0$ and $K_{B}=1$.


## CSMA/CD (ETHERNET)

1. The adapter obtains a datagram from the network layer, prepares a link-layer frame, and puts the frame adapter buffer.
2. If the adapter senses that the channel is idle (that is, there is no signal energy entering the adapter from the channel), it starts to transmit the frame. If, on the other hand, the adapter senses that the channel is busy, it waits until it senses no signal energy and then starts to transmit the frame.
3. While transmitting, the adapter monitors for the presence of signal energy coming from other adapters using the broadcast channel.
4. If the adapter transmits the entire frame without detecting signal energy from other adapters, the adapter is finished with the frame. If, on the other hand, the adapter detects signal energy from other adapters while transmitting, it sends a jam signal and aborts the transmission.
5. After aborting, the adapter waits a random amount of time and then returns to step (2.)

## CSMA/CD (ETHERNET)

| jam Time t | Event |
| :---: | :---: |
| signal 48 bit | $A$ and $B$ begin transmission |
| 245 | $A$ and $B$ detect collision |
| $245+48=293$ | $A$ and $B$ finish transmitting jam signal |
| $293+245=538$ | B's last bit arrives at A; A detects an idle channel |
| $538+96=634$ | A starts transmitting |
| $293+512=805$ | B returns to Step 2, B must |
| $K_{n}=1$ | sense idle channel for 96 bit times before it transmits |
| $634+245=879$ | A's transmission reaches B |

## Protocol Efficiency

## Slotted ALOHA



Node 2 $\square$

$\square$
$\square$

## Slotted ALOHA

## Why is $\mathrm{E}(\mathrm{N}, \mathrm{p})=\mathrm{N}^{*} \mathrm{p}(1-\mathrm{p})^{\mathrm{N}-1}$



- We only want 1 node to transmit (no collision) in a given slot.
- Probability to transmit = p ---for-one-node---> 1*p
- Probability not to transmit = $(1-p)$---for-(N-1)-nodes---> $(1-p)^{N-1}$
- So for one node to transmit alone the probability is $p^{*}(1-p)^{N-1}$
- However, we don't care about which node manages to transmit without collision, so we multiply the above probability by the number of nodes.
$>$ Therefore, $\mathrm{E}(\mathrm{N}, \mathrm{p})=\mathrm{N}^{*} \mathrm{p}(1-\mathrm{p})^{\mathrm{N}-1}$


## Pure ALOHA



Figure 6.11 Interfering transmissions in pure ALOHA

## In pure ALOHA, the efficiency formula is

$$
E(N, p)=N^{*} p^{*}(1-p)^{2(N-1)}
$$

## Let's prove this too!

## Pure ALOHA

The proof is actually the same, with one small difference.


Figure 6.11 Interfering transmissions in pure ALOHA

- Again, we want a node it to transmit alone, so there are no collisions.
- But now, transmissions are not bounded by slots!
- So the rest of the nodes must stay quiet both during the transmission of node $\mathrm{i}, \mathrm{AND}$ for a period of time before the beginning of the transmission of node i , to avoid the transmission of node i happening while someone else transmits (collision!).


## Question: How long must this period be?

Answer: Equal to the length of transmissions!

- So 1-transmission-long before node i transmits, and 1-transmission-long while node i is transmitting, that means 2 1-transmission-long periods, within which all the other nodes have a probability of NOT transmitting equal to (1-p).
- Thus the required "silence" happens with probability (1-p) $)^{2(N-1)}$.
- The rest of the proof is the same! Node i transmits with probability p, so 1*p.
- Again, we don't care which specific node manages to successfully transmit, so we multiply the final probability by $\mathbf{N}$.

And therefore, $E(N, p)=N^{*} \mathbf{p}^{*}(\mathbf{1 - p})^{\mathbf{2 ( N}-1)}$

Final ALOHA question: which is more efficient, slotted or pure ALOHA? Why?

## CSMA/CD (ETHERNET)

Assume an Ethernet system where the propagation delay is 512-bit times and the minimum frame size is 1024 bits.

Calculate the efficiency of the system and discuss how the propagation delay and minimum frame size affect the efficiency.


## Given:

- Propagation delay, $d_{\text {prop }}=512$ bit-times
- Minimum frame size, $d_{\text {trans }}=1024$ bits

The efficiency $(\eta)$ of the system can be estimated using the following formula:

$$
\eta=\frac{1}{1+5 \times \frac{d_{\text {drop }}}{d_{\text {trans }}}}
$$

$$
\eta=\frac{1}{1+5 \times \frac{512}{1024}} \rightarrow \eta=\frac{1}{1+5 \times \frac{1}{2}} \rightarrow \quad \eta=\frac{1}{1+2.5} \rightarrow \eta \approx 0.2857 \text { or } 28.57 \%
$$

## EDC ( Error-Detection and -Correction)

Parity check: When checking vector / row / column:


Let's remember the 2D parity check:

Which one has the error?
Can we identify it?


## CRC (Cyclic Redundancy Check)

Let's say our data sequence $D$ is 1101 and we are using a 3-bit generator G of 101.

110100 (Original data with padding)
/ 101 ||| (Generator)
(First XOR operation, align G with the first '1' in D) (Generator aligned with the first '1' after the XOR)

0100 (Result of XOR, now align G with the first '1' again)
(Generator)
010 (Result of XOR, and this is less than the length of G)
So $R=10$

## Let's see if that worked:

Receiver gets $D+R$ and already knows $G$ (it was already agreed upon).

In out case, $\mathrm{D}=1101$ and we calculated
$R$ to be $R=10$, so $D+R=110110$
Let's do the derivation.


## Thank you!

