Aloha protocol

• General principles

• History

• Performance

• Extensions
Road map

Design protocol based on radio transmissions allowing large number of geographically* scattered users to communicate via a central computer (CC)

* University of Hawaii, late 60s
Constraints

• Use as little radio frequencies as possible

• Use as simple terminals as possible
Solution: N. Abramson, 1970

- Unique radio frequency in each way (users - CC, CC - users)
  Two 100khz channels at 407.50mhz and 413.475mhz
- Users send messages to CC whenever they want
  msg size = 704 bits; thru. = 24 Kbs; duration = 29 ms
- Non-acknowledged messages must be retransmitted after random delay
  200 ms < Expected retransmission delay < 1500
Features of Aloha

- Contention MAC protocol
- Collisions solved by random retransmissions
- Decentralized protocol (robust to terminal failures)
- Asynchronous transmissions
Main innovations

- Radio transmissions
  Alternative: underwater cables

- Free access to channel
  Alternative: time-division multiplexing (TDM), frequency-division multiplexing (FDM)
Q: Is it worth deploying such a protocol? What is the maximum throughput (goodput) Aloha can sustain?
Model

- $k$ active users
- $\tau$ = duration message transmission
- $T^n_i$ = transmission time of $n$th new message of user $i$
  \[ \{T^n_i\}_n \text{- stochastic process, rate } \lambda \]
  \[ 1/\lambda = \lim (1/N) \sum_{1 \leq n \leq N} (T^n_{i+1} - T^n_i) \]

- $T^n$ = transmission time of $n$th new message
  \[ \{T^n\}_n \text{- stochastic process, rate } r := k\lambda \]
  \[ 1/r = \lim (1/N) \sum_{1 \leq n \leq N} (T^{n+1} - T^n) \]

- $t^n$ = transmission time of $n$th message, new or not
  \[ \{t^n\}_n \text{- stochastic process, rate } R \geq r \]
• $t_n =$ transmission time of $n$th message, new or not

Assumption: $\{t_n\}_n$ is Poisson process with rate $R$

Reminder:
• $P(t_{n+1} - t_n < x) = 1 - e^{-xR}$ \hspace{1cm} x > 0

• $P(m$ transmissions in $(s, s+a)) = (Ra)^m e^{-aR}/m!$

• # arrivals in two disjoint intervals are independent rvs
Analysis

\[ R = r + R \times P(\text{collision}) \]

\[ P(\text{collision}) = P(\text{at least 1 trans. in } 2\tau) = 1 - P(0 \text{ trans. in } 2\tau) = 1 - e^{-2\tau R} \]

\[ R = r + R(1- e^{-2\tau R}) \]

\[ r = R e^{-2\tau R} \quad \Rightarrow \quad r\tau = R \tau e^{-2\tau R} \]
Analysis (con’t)

\[ r \tau = R \tau e^{-2\tau R} \]

- \( r \tau \) = offered load
- \( R \tau \) = total traffic

\[ f: x \rightarrow xe^{-2x} \max \text{ for } x = \frac{1}{2}, f(0.5) = \frac{1}{2e} \]

Maximum throughput: \(~18.6\%\)
Analysis (con’t)

\[ f: x \to xe^{-2x} \text{ maximum for } x = 1/2, \ f(0.5) = 1/(2e) \]

Maximum throughput: \(~18.6\%\)
Analysis (con’t)

\[ k_{\text{max}} = ? \]

\[ r = k \lambda \implies k = r \tau/(\lambda \tau) \]

\[ \implies k_{\text{max}} = \frac{\text{(channel capacity)}}{\lambda \tau} \]

\[ \implies k_{\text{max}} = 1/(2e\lambda \tau) \]

<table>
<thead>
<tr>
<th>1/λ</th>
<th>60s</th>
<th>30s</th>
<th>1sec</th>
</tr>
</thead>
<tbody>
<tr>
<td>( k_{\text{max}} ) (Th 18.6%)</td>
<td>324</td>
<td>162</td>
<td>5</td>
</tr>
<tr>
<td>Nb users (Th. 15%)</td>
<td>264</td>
<td>132</td>
<td>4</td>
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Results robust to modeling assumption (Poisson)
How to improve performance?

- Synchronize transmission (double channel capacity, 37% - still low)

- Listen to channel before transmitting (CSMA protocol)

- Listen to channel before transmitting and during transmission (CSMA-CD protocol) ➤ toward Ethernet protocol
N. Abramson, The Aloha System: Another alternative for computer communications

https://www.clear.rice.edu/comp551/papers/Abramson-Aloha.pdf