Brief Announcement:

Unbounded Contention Resolution in Multiple-access Channels

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Shared Resource Contention

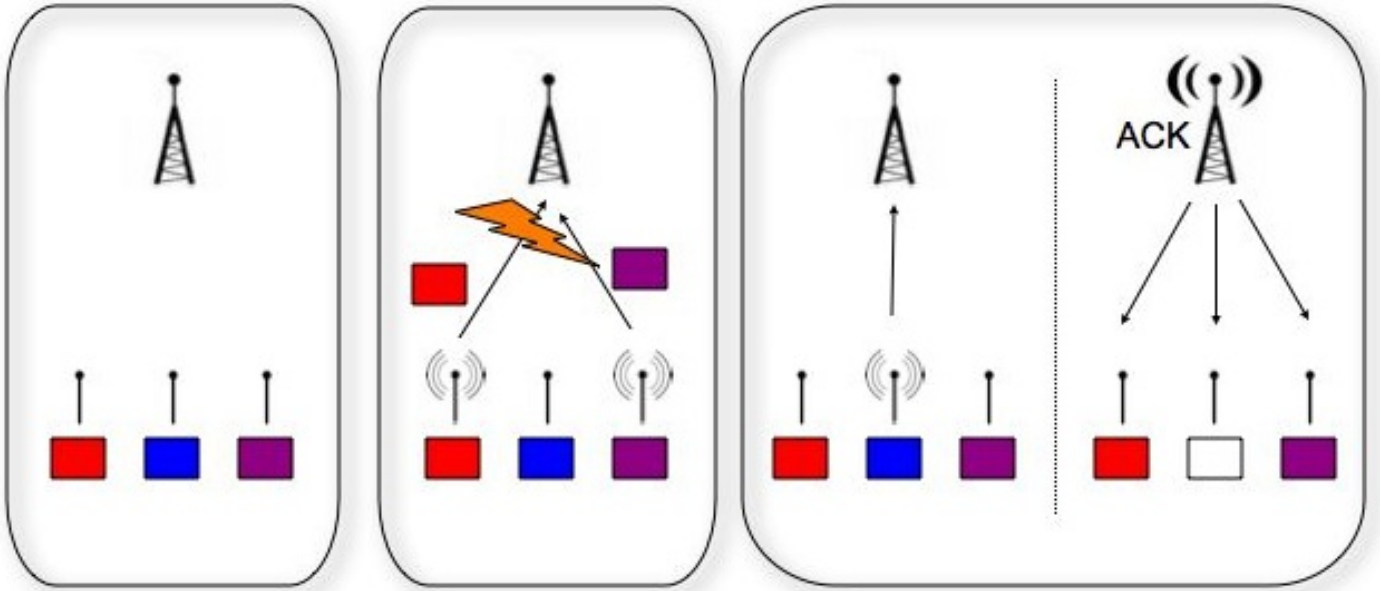
- k-Selection in Radio Networks:

  "unknown size-k subset of n network nodes
  must access a unique shared channel of communication,
  each of them at least once."

- Q: k-Selection in $O(k)$ with n and k unknown?

Radio Network Model

- usual assumptions (time slotted, negligible computation cost, etc.)
- single-hop.
- *static* k-Selection (*batched* message arrivals).
- communication through radio broadcast on a shared channel:
  - no message transmitted $\rightarrow$ background noise.
  - more than one node transmits $\rightarrow$ interference noise.
  - exactly one node transmits $\rightarrow$ all other nodes receive message and the sender receives an ack.
  - nodes can not distinguish between interference and background noise.



Related Work

- Gerèb-Graus, Tsantilas'92:
  arbitrary k-relations realization in $\Theta(k + \log n \log\log n)$ w.h.p.
  $\rightarrow$ known k.

- Greenberg, Leiserson'89:
  randomized routing of bounded number of messages in fat-trees
- Farach-Colton, Mosteiro'07:
  sensor network gossiping
  linear sawtooth technique embedded
  $\rightarrow$ known n, asymptotic analysis.

- Bender, Farach-Colton, Kuszmaul, Leiserson'05:
  Loglog-iterated Back-off unknown k, n
  $\rightarrow \Theta(k \log\log k / \log\log\log k)$ w.h.p.
  linear sawtooth technique described, no analysis.

- Fernández-Anta, Mosteiro'10:
  Log-fails Adaptive in $< 8k + O(\log^2(1/\varepsilon))$, w.p. $\geq 1 - 2\varepsilon$
  $\rightarrow$ known n.

Results

Randomized k-selection protocols
for batched arrivals in one-hop Radio Networks:

- One-fail Adaptive $< 8k + O(\log^2 k)$, w.p. $\geq 1 - 2/(1+k)$
- Exponential Back-on/Back-off $< 4(e+1)k$, w.p. $\geq 1 - 1/k^{\Theta(1)}$

Time-optimal (with high probability, modulo a small constant)
work without collision detection, unknown k and n.

- improves over Log-fails Adaptive removing knowledge of n.
- EBOBO (sawtooth) analyzed down to constants.
- experimental evaluation.

One-fail Adaptive $\rightarrow 8k + O(\log^2 k)$ w.p. $\geq 1 - 2/(1+k)$

Protocol for node x (without constants)

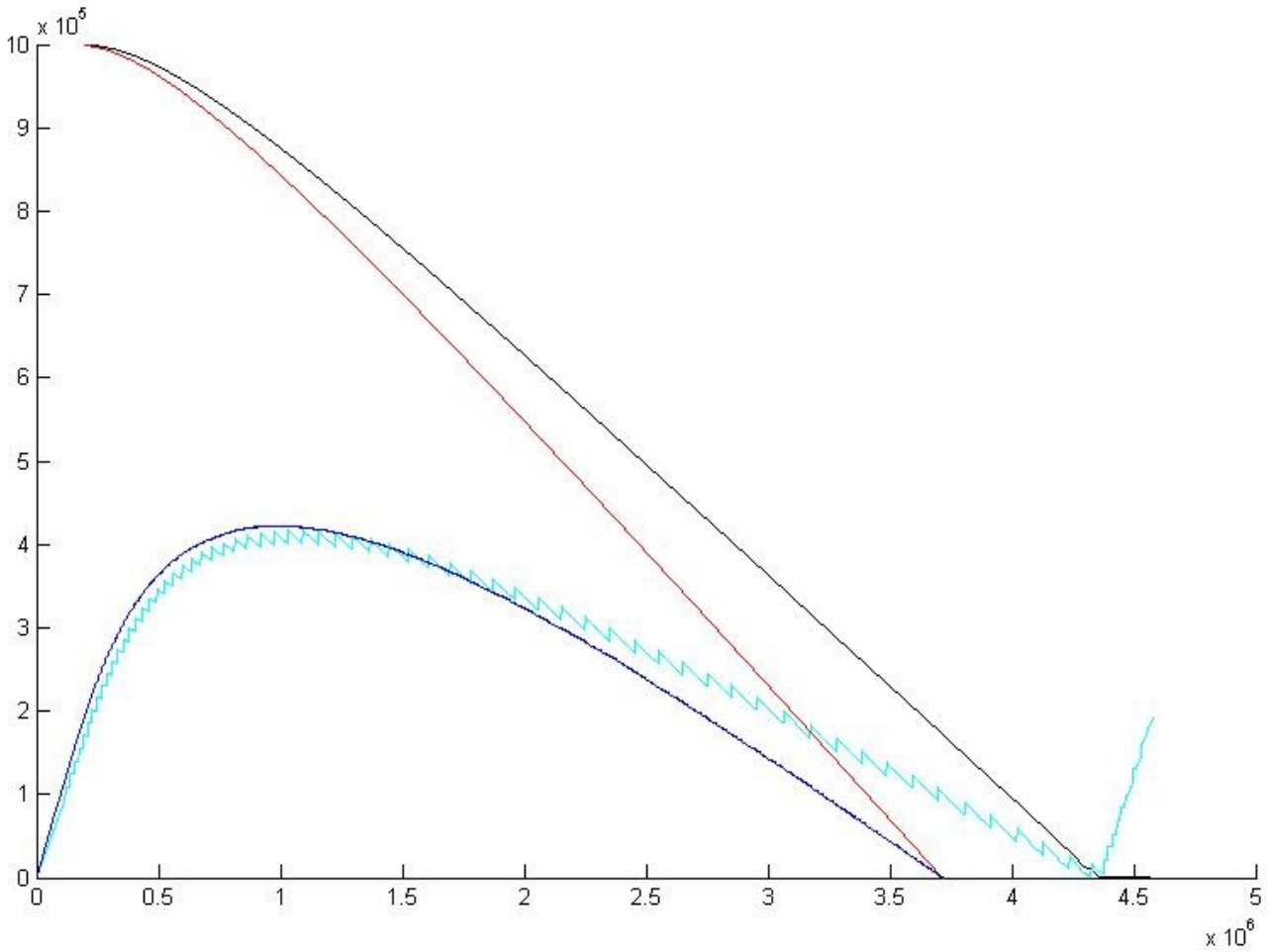
Concurrent Task 1:
- $\sigma = 0$, $\hat{\kappa} = 4$. (msg-received counter, density estimate)
- for each communication step
  - if step is even (Algorithm BT)
    - transmit $\langle x, message \rangle$ with probability $1/(1 + \log(\sigma + 1))$.
  - if step is odd (Algorithm AT)
    - transmit $\langle x, message \rangle$ with probability $1/\hat{\kappa}$.
    - $\hat{\kappa} = \hat{\kappa} + 1$. (new estimate)

Concurrent Task 2:
- upon receiving a message from other node
  - $\sigma = \sigma + 1$. (update counter)
  - if step is even (Algorithm BT)
    - $\hat{\kappa} = \max\{\hat{\kappa} - 3, 4\}$. (new estimate)
  - if step is odd (Algorithm AT)
    - $\hat{\kappa} = \max\{\hat{\kappa} - 4, 4\}$. (new estimate)

Concurrent Task 3:
- upon delivering message, stop.

One-fail Adaptive

Illustration of estimate progress

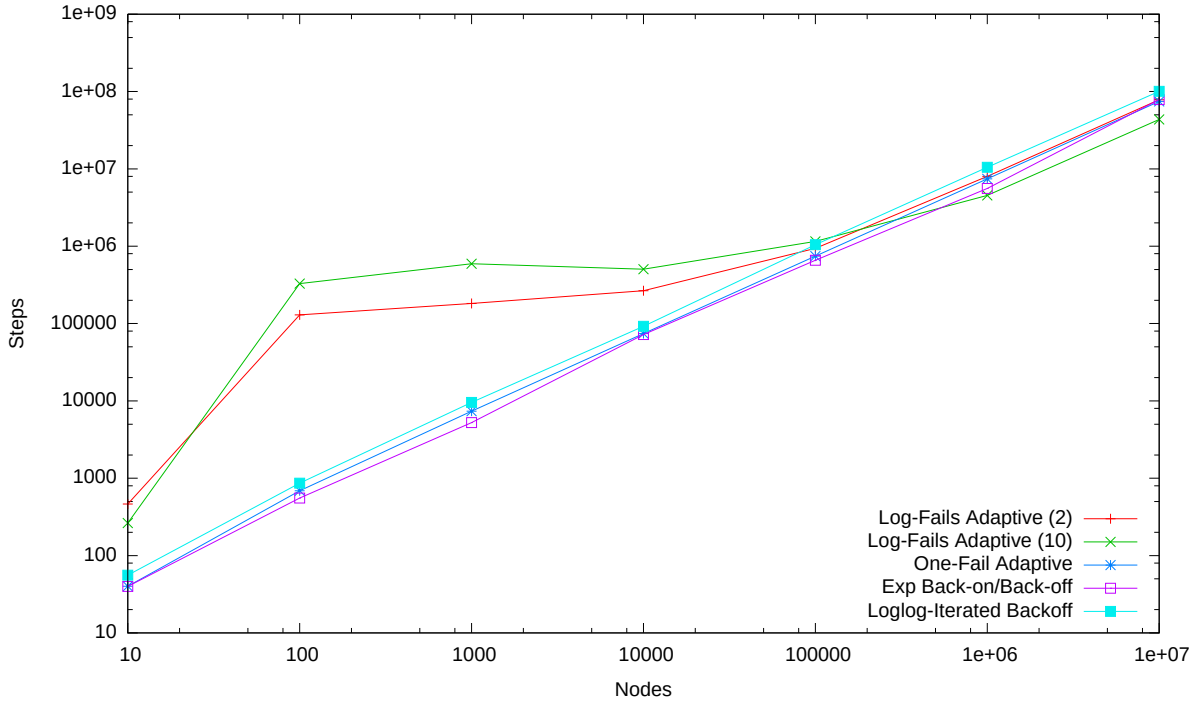


Exponential Back-on/Back-off $\rightarrow 4(e+1)k$, w.p. $\geq 1 - 1/k^{\Theta(1)}$

Window size adjustment

for $i = \{1, 2, \dots\}$
  $w = 2^i$
  while $w \geq 1$
    choose uniformly a step within the next w steps
    $w = w(1 - 1/e)$

Simulations



k	10	10^2	10^3	10^4	10^5	10^6	10^7	Analysis
Log-fails Adaptive $\xi_t = 1/2$	46.4	1292.4	181.9	26.6	9.4	8.0	7.8	7.8
Log-fails Adaptive $\xi_t = 1/10$	26.3	3289.2	593.8	50.3	11.5	4.5	4.4	4.4
One-fail Adaptive	4.0	6.9	7.4	7.4	7.4	7.4	7.4	7.4
Exp Back-on/Back-off	4.0	5.5	5.2	7.2	6.6	5.6	7.9	14.9
Loglog-iterated Back-off	5.6	8.6	9.6	9.2	10.5	10.5	10.1	$\Theta\left(\frac{\log\log k}{\log\log\log k}\right)$

Ratio steps/nodes as a function of the number of nodes k.

Thank you