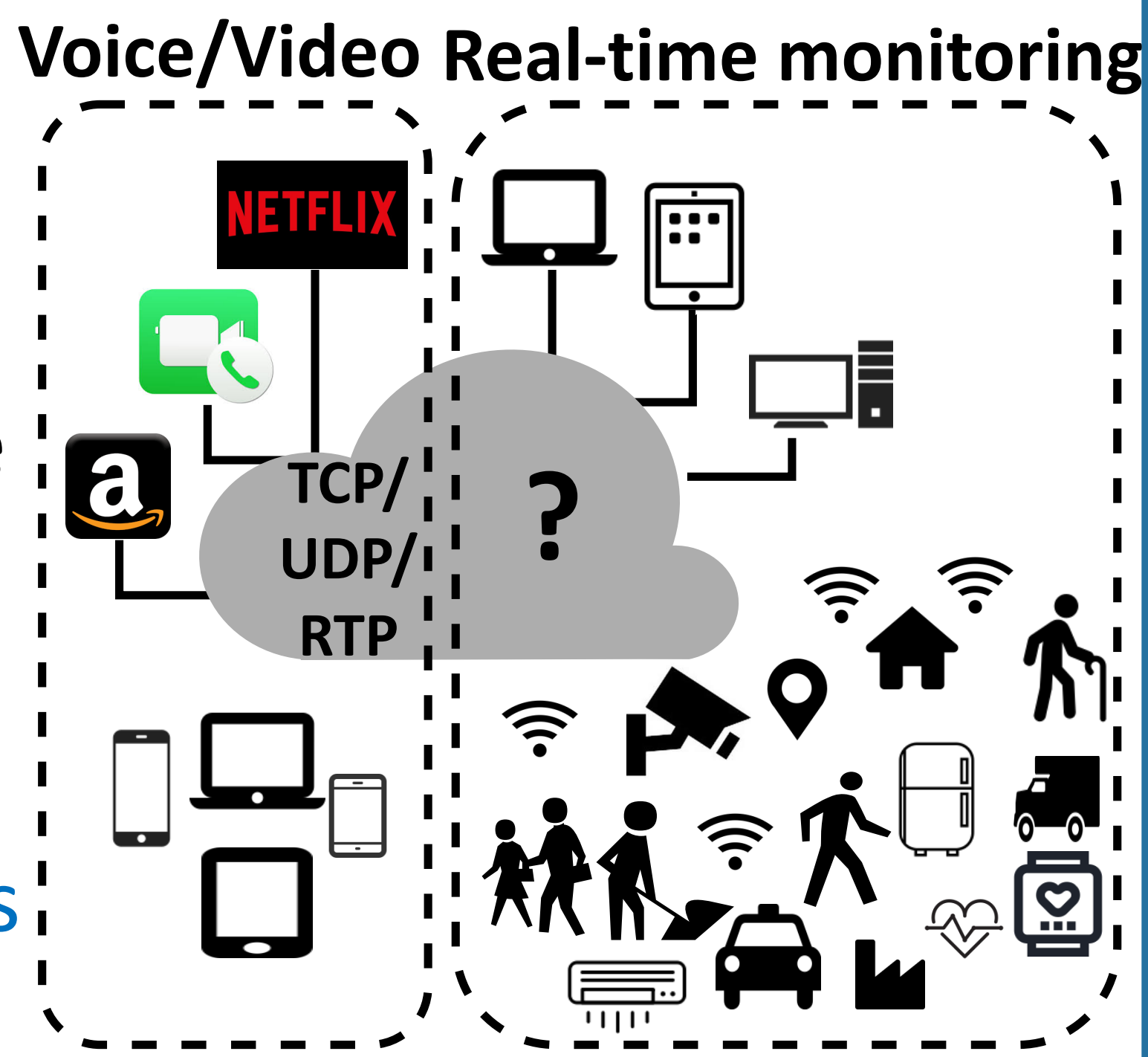


Tanya Shreedhar\*, Sanjit K. Kaul\* and Roy D. Yates#

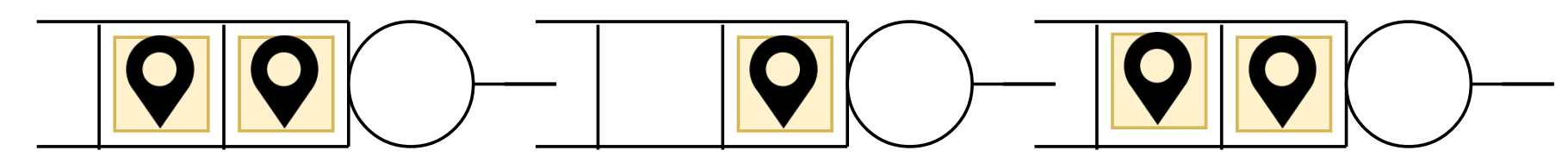
\*Wireless Systems Lab, IIT-Delhi, #WINLAB, Rutgers University

## Monitoring in Smart Environments

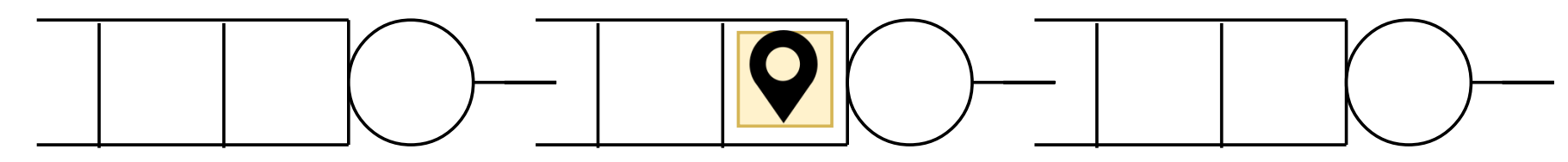
- 50.1 billion IoT devices connected to internet by 2020 [1]
- Traditional Voice/Video/File download desire higher throughput/ low delay and jitter
- Real-time monitoring values freshness of an update
  - Is highly loss resilient



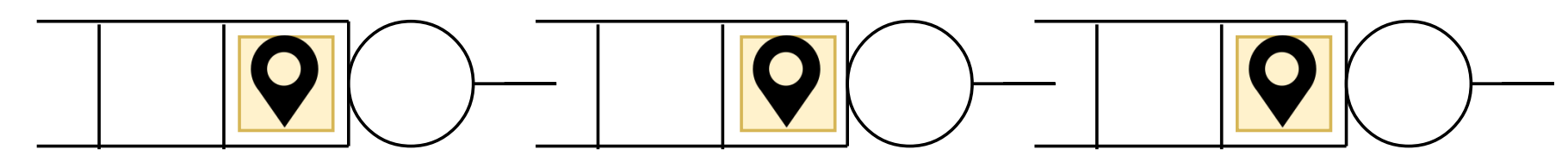
## Good Age Control Strategy



Update Rate-High, Delay-High, Age-High



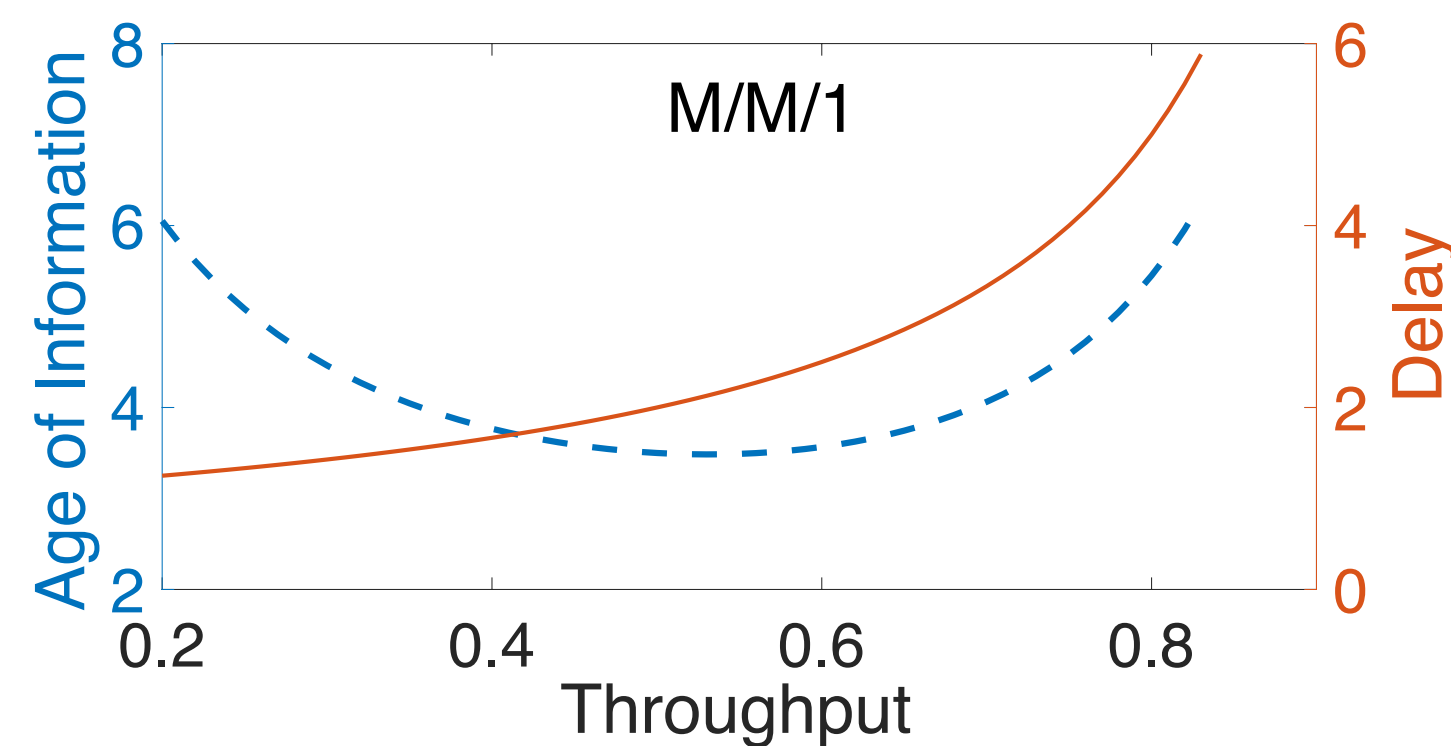
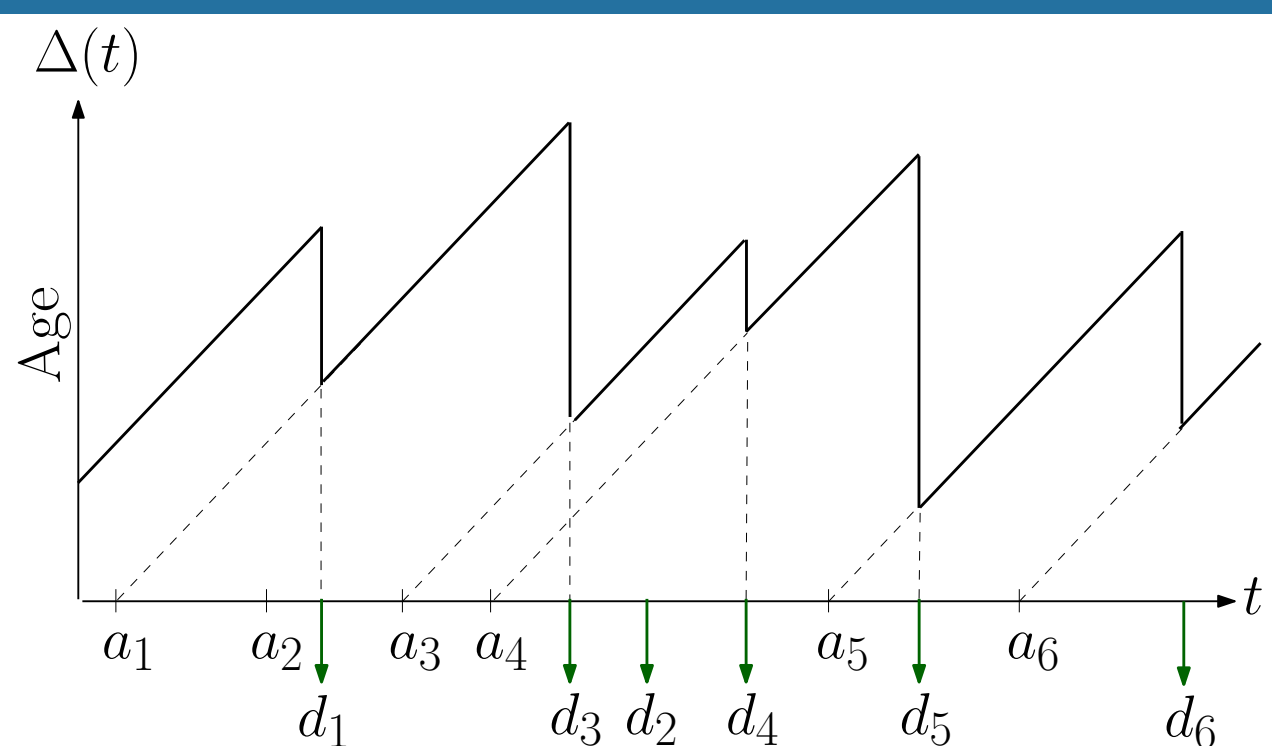
Update Rate-Low, Delay-Low, Age-High



Ideal snapshot of updates in transit

Put as many updates in transit so that they avoid waiting for other queued updates

## Age! Neither Throughput Nor Delay



Age = Measure of freshness of update at monitor

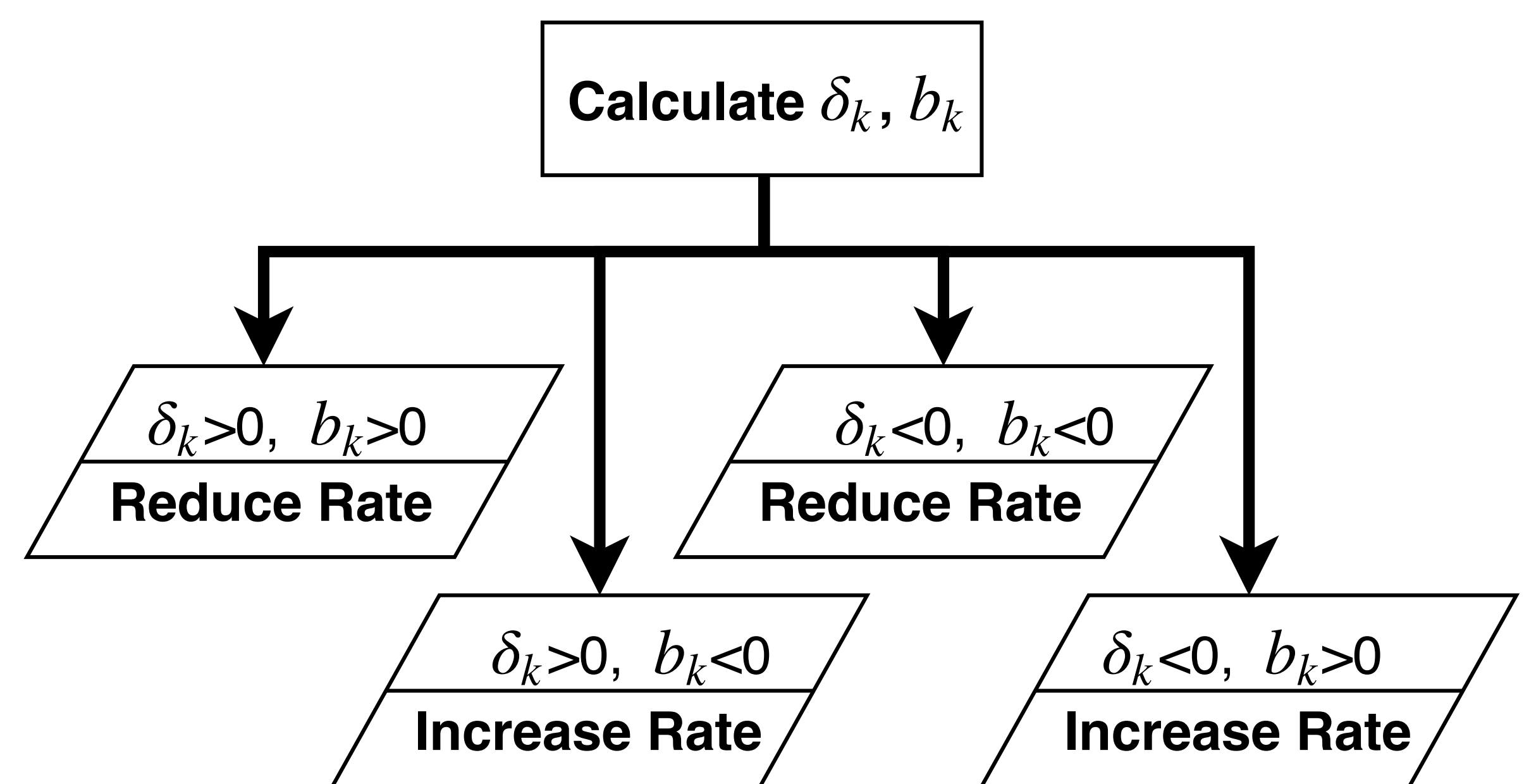
Age of Information (Aoi) = Time-Average Age

High rate of update → congestion/delays → High Aoi

Low rate → infrequent updates/old estimates → High Aoi

Aoi minimizing update rate exists!

## Control Algorithm

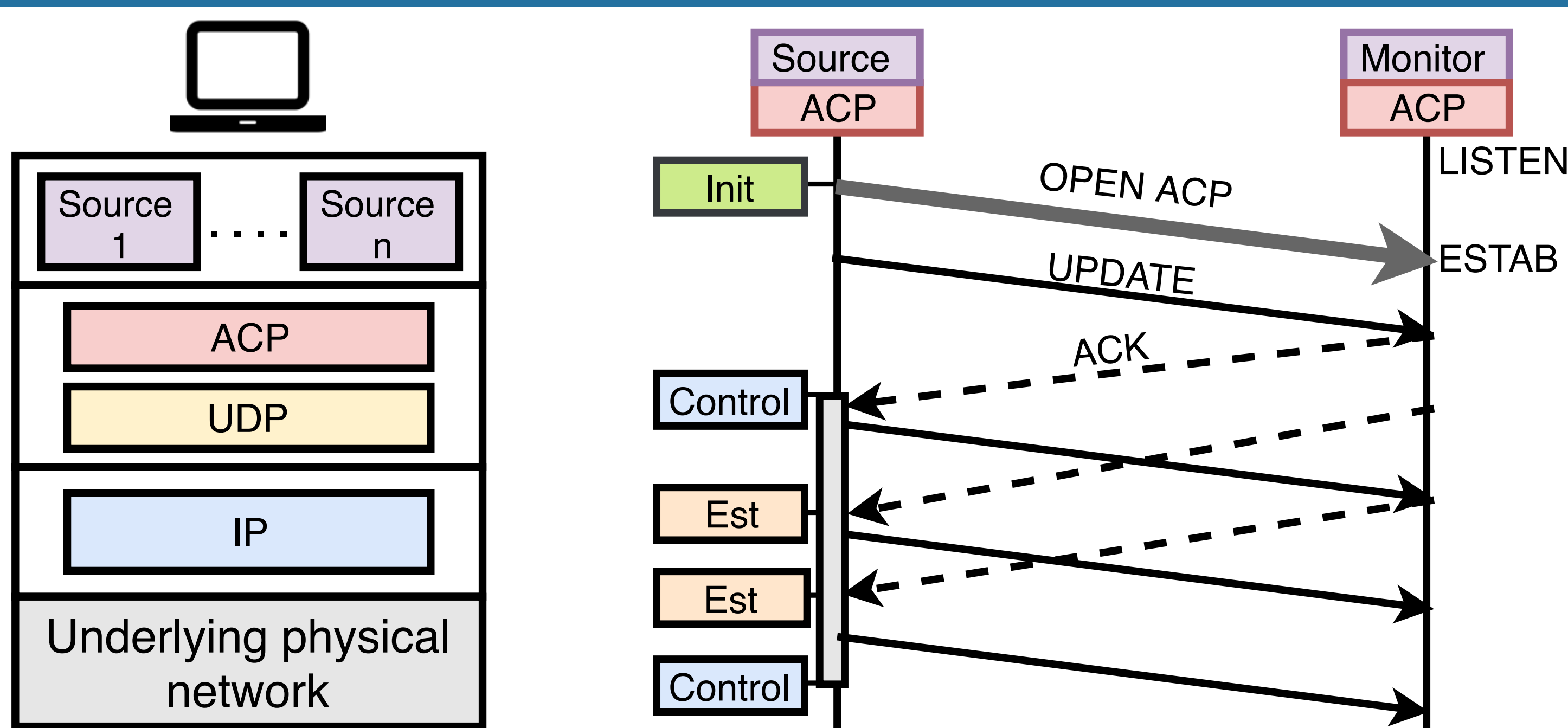


## Challenge: Age Control Over the Internet

AIM: Minimize Aoi of Updates at the Monitor

- Adapt rate to changing network congestion conditions
- Use only end-to-end measurements of the network

## ACP Stack and Connection



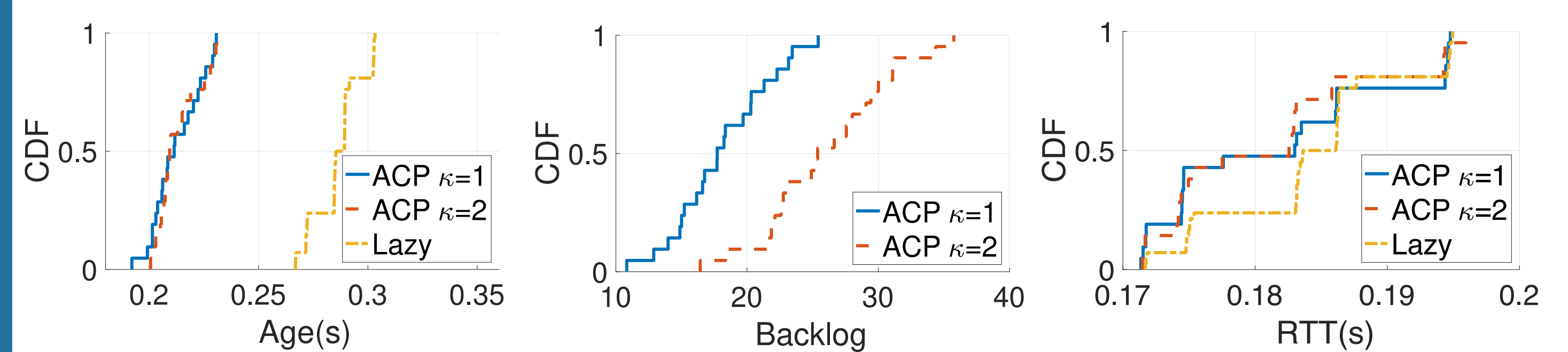
Init: Sets the initial send rate

Control: Decides the sending rate till next control epoch based on changes in Age  $\delta_k$  and changes in Backlog  $b_k$

Est: Updates the average RTT on reception of ACK

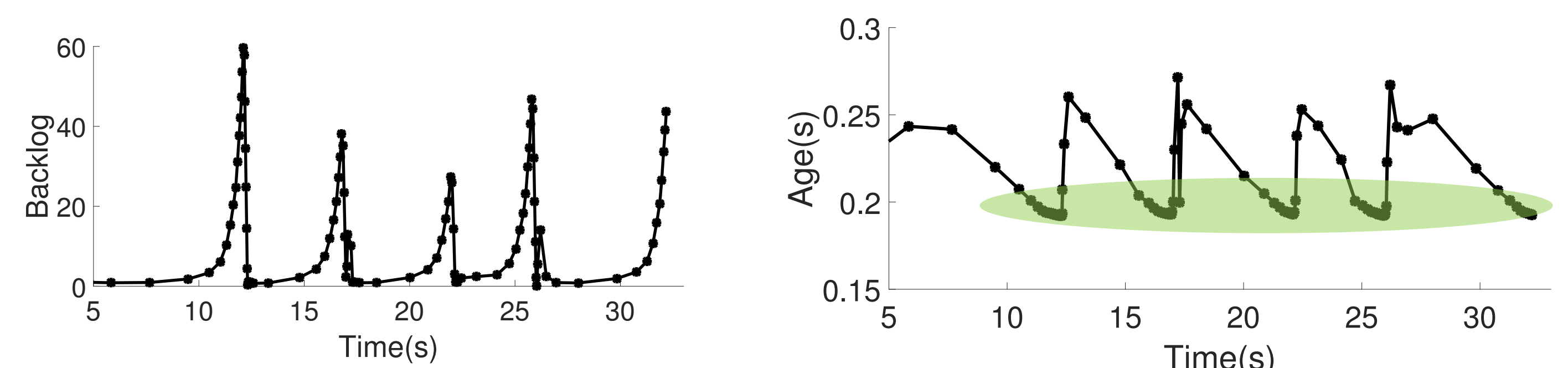
## Updates Over the Internet

Setup: Source in India sending updates to a monitor in Finland ( $\approx 20$  hops)



Results: ➤ 28% improvement over Lazy (once per RTT)  
➤ However, similar RTTs!

Increases backlog conservatively till age decreases  
Decreases backlog aggressively once age increases



## Future Work

- TCP friendliness, fairness between ACP sessions
- Evaluate ACP over dense wireless networks
- Analytical understanding of Age Control over the Internet

## References

- [1] Broadband by the numbers, 'https://www.ncta.com/broadband-by-the-numbers'
- [2] Kaul, Sanjit, Roy Yates, and Marco Gruteser. "Real-time status: How often should one update?." *INFOCOM*, 2012
- [3] Yates, Roy D. "Lazy is timely: Status updates by an energy harvesting source." *ISIT*, 2015