

# **CONTRACTS: PRACTICAL CONTRIBUTION INCENTIVES FOR P2P LIVE STREAMING**

**An Overview by Alex Loeb**

# DISTRIBUTING LIVE CONTENT

- Why it's different
- What's been done
- What's wrong with what's been done
- What Contracts improves
- How well Contracts' improvements work



# WHY LIVE CONTENT IS DIFFERENT

- Not all of the content is available immediately
- All available content expires eventually
- Heterogeneous capacities become significant



# WHAT'S BEEN DONE

- In the beginning ... there was IP Multicast ... sort of
- Approximate Multicast with a Tree Overlay
  - Narada, Overcast, Yoid
    - SplitStream later improves leaf node utilization
- Mesh-based Overlay Network (P2P)
  - Coolstreaming/DONet
- P2P-VoD, streaming, but not live
  - PPLive
- P2P Incentives
  - Bilateral exchange, multilateral exchange
- Live Streaming P2P Incentives
  - Many and diverse...



# LIVE STREAMING INCENTIVES

- Tit-for-Tat
  - Common (non-streaming) P2P mechanism
- Rank order-based incentive through Service Differentiation
  - Rank all peers based on contributions (tournament)
- Use Multiple Trees (differentiated services)
  - Only subscribe to subset of trees based on sharing
- BAR Gossip (and later FlightPath)
  - Tit-for-Tat with a twist
  - Exchange data, but require a final key exchange to make the data useful



# HONORABLE MENTION

- Fair File Swarming with FOX
  - Not concerned with Streaming at all, but...
  - Uses Mutually Assured Destruction to achieve provably optimal performance in the presence of selfish nodes



# LIVE STREAMING INCENTIVES (PROBLEMS)

- Tit-for-Tat (Bilateral exchange)
  - More on this later...
- Rank order-based incentive through Service Differentiation
  - Low capacity nodes get hurt
- Use Multiple Trees (differentiated services)
  - Requires all nodes to play fair
- BAR Gossip (and later FlightPath)
  - See Tit-for-Tat above...



# WHAT CONTRACTS IMPROVES

- Builds on PPLive
- Shows Bilateral Exchange performs poorly
- Reward Global Contributions
  - Strengthen incentives
  - Improve performance



# PPLIVE OVERVIEW

- P2P Live/On-Demand Streaming
  - Seed Servers hosting content
  - Trackers coordinating users watching same content
- All peers maintain a large set of directly connected peers
- Seed Servers are a last resort source
- Peers do not prioritize other peers
  - High and Low contributors treated as equals
  - Swarming with bilateral exchange



# PROBLEMS WITH BILATERAL EXCHANGE IN PPLIVE

- Heterogeneous Capacity among nodes
  - Study shows top 10% of nodes provide 58% of total capacity in PPLive
  - Tit-for-Tat
    - Either everyone transfers at the lowest nodes capacity
    - Or all the nodes who can't keep up get left out
- Limited Bandwidth Needs
  - No reason for high capacity nodes to over take production rate
- Data Blocks are not all equal
  - In Live Streaming, blocks expire quickly
  - Reduction in mutually beneficial trade opportunities



# BILATERAL EXCHANGE AND LIVE STREAMING

## ○ Delay Sensitivity

- **THEOREM 2** *Any topology in which a peer  $i$  has lower bandwidth than peer  $j$  but  $i$  has more descendants than  $j$  has higher average block delay than the topology obtained by swapping  $i$  and  $j$  if one of the following two conditions hold: (a) the topology is a balanced tree, or (b)  $i$  is an ancestor of  $j$ .*

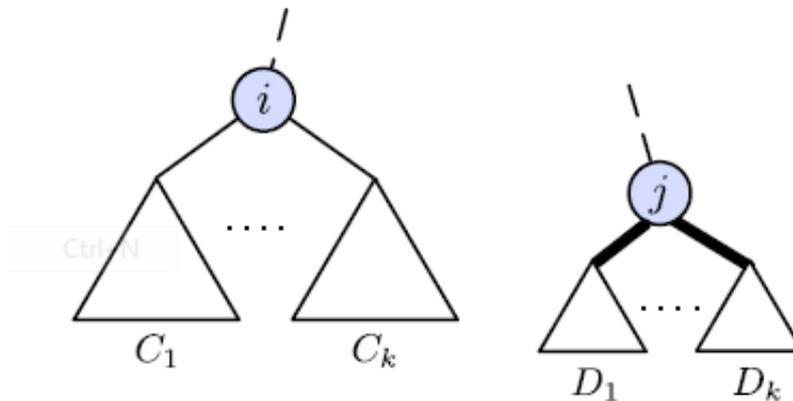


Figure 2: Illustration for Theorem 2: Node  $j$  has higher upload capacity than node  $i$  but has fewer descendants.



# BILATERAL EXCHANGE AND LIVE STREAMING

- What Theorem 2 means...
  - Higher capacity nodes should be **closer to the source** (to reduce delay)
  - ...but then Higher capacity nodes **get newer blocks first** (before lower capacity blocks)
  - ...but then Higher capacity nodes **don't benefit from lower capacity nodes**
  - ...but all nodes **evaluated by their utility** (using Bilateral Exchange)
  - ...so Bilateral Exchange is **bad for delay** (because low capacity nodes have to be closer to the source)



# ALIGNING INCENTIVES AND PERFORMANCE

- Put high capacity nodes close to the source
  - Optimizes distribution topology to reduce delay and maximize utilization
  - They get better quality playback

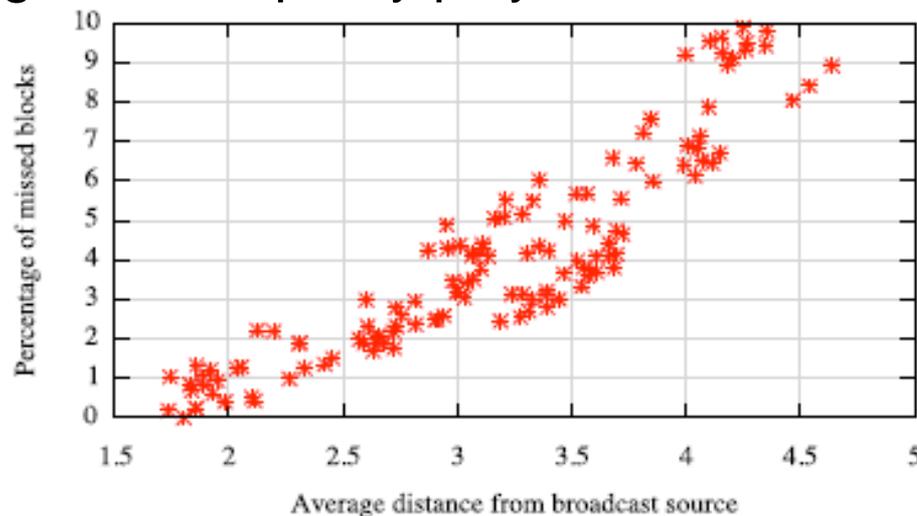
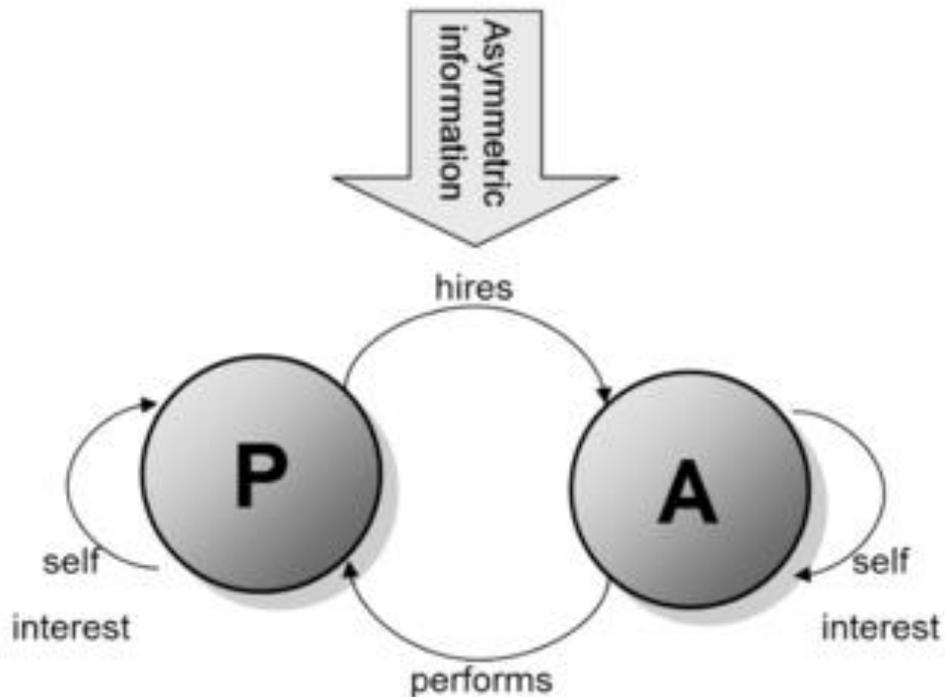


Figure 4: The fraction of blocks missing playback deadlines as a function of distance from the broadcast source. Playback quality is best for clients nearest to the source.



# THE PRINCIPAL-AGENT PROBLEM

- “The problem of motivating a party to act on behalf of another” - [http://en.wikipedia.org/wiki/Principal-agent\\_problem](http://en.wikipedia.org/wiki/Principal-agent_problem)
- Key to Contracts is “role asymmetry”

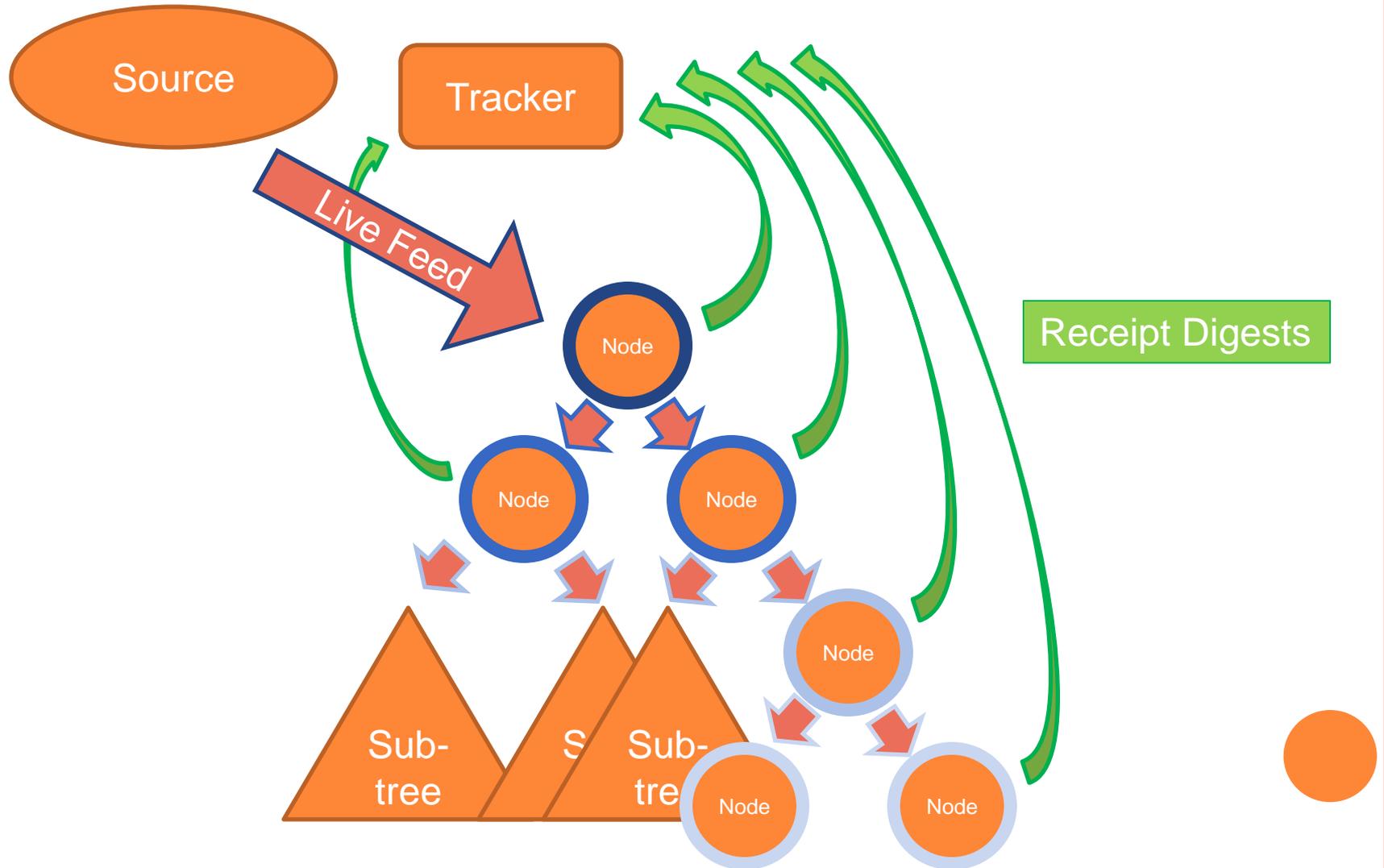


# CONTRACTS

- “Provider provides service proportional to one’s ability to replicate the data further”
- Provide Global Topology Optimization
  - Use a universal Contract to cause high capacity nodes to move closer the source
  - Track global information to facilitate this



# CONTRACTS TOPOLOGY



# HEY! I'M CONTRIBUTING ... REALLY, I SWEAR!

- Centralized Verification by the Tracker
  - Each node keeps receipts of all transactions
  - Each node sends receipt digest to Tracker periodically
  - Receipts and Digests signed for validity
- Central Tracker must reassemble receipts and compute node contributions
- Central Tracker then sends the node a new list of peers which determine that node's place in the topology



# CONTRACTS EVALUATION

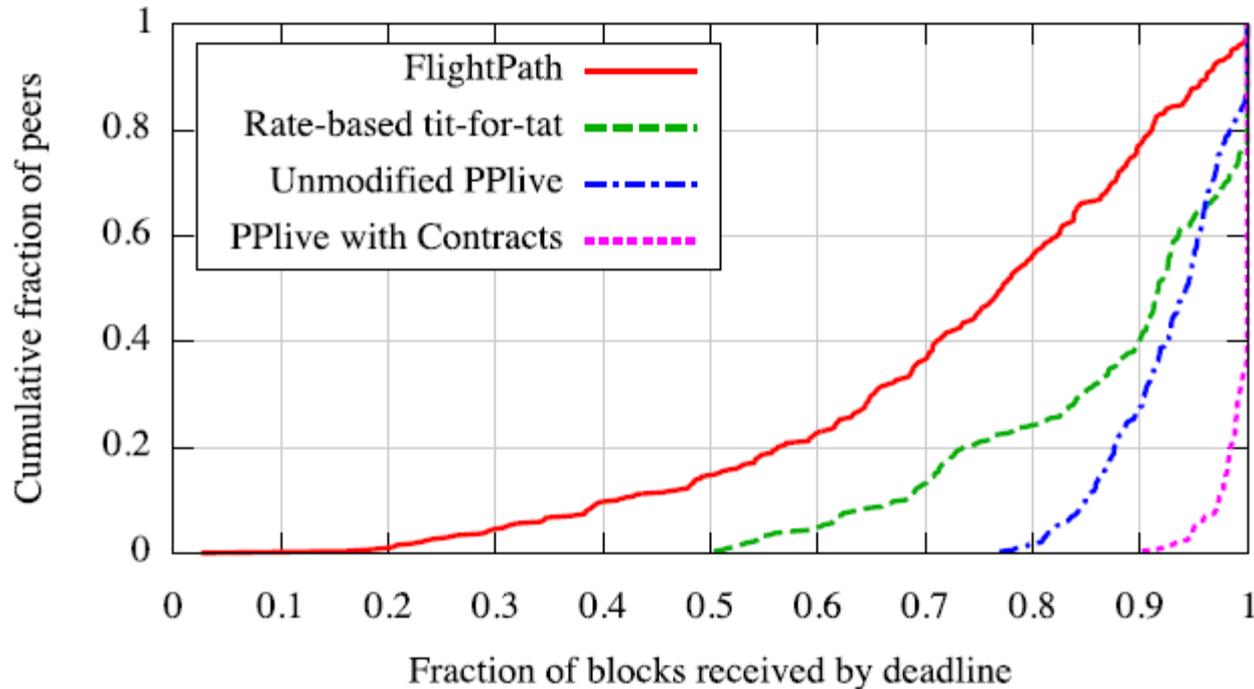


Figure 8: Performance comparison of unmodified FlightPath, PPLive, rate-based tit-for-tat, and *Contracts*.



# CONTRACTS EVALUATION

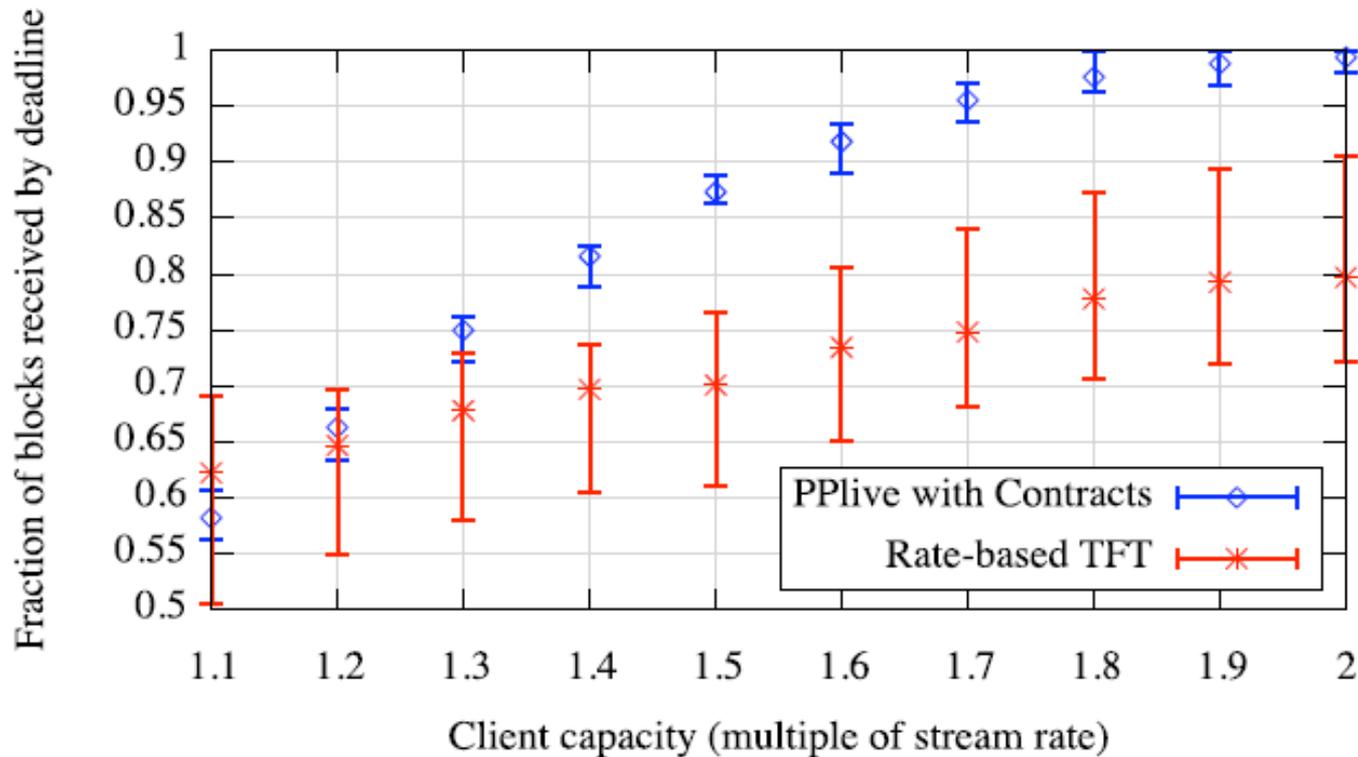


Figure 9: Delivery rate as a function of contribution



# CONTRACTS EVALUATION

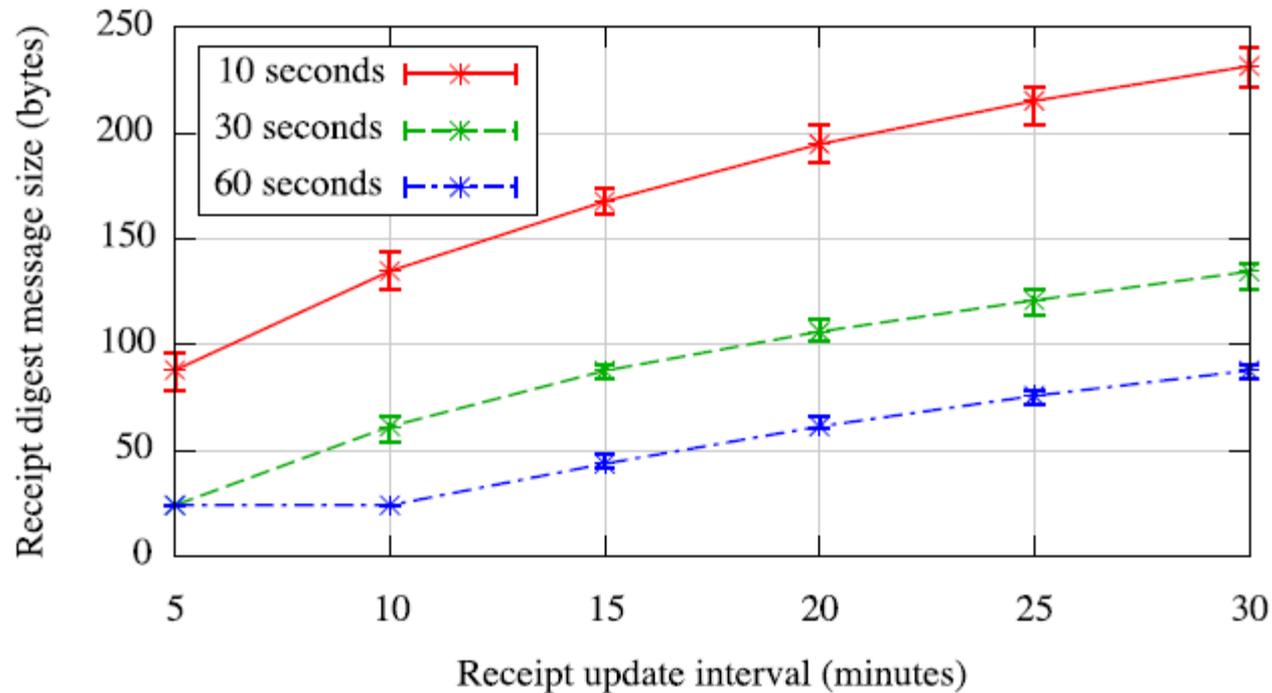


Figure 10: The size of receipt digest messages as a function of the digest update interval.



THANKS!

