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Consistency in Distributed Systems, and Automatic Network Configuration with Dynamic Churn Prediction

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Introduction

Consistency in DHTs

Churn Prediction with DHTs

Why DHT? (1)

- DHT in P2P
  - Very popular use-case: file-sharing, BitTorrent (KAD)
  - DHT/P2P is **much more** than file-sharing
- DHT in IoT
  - A DHT-Based Discovery Service for the Internet of Things, Federica Paganelli and David Parlanti
  - Implementing Secure P2P-ONS, Benjamin Fabian,
  - A distributed control plane for the Internet of Things based on a Distributed Hash Table, Jaime Jiménez Bolonio, Manuel Urueña, Gonzalo Camarillo

Why DHT? (2)

- DHT in IoT
  - Interconnecting smart objects through an overlay networking Architecture, Anastasios Zafeiropoulos, Athanassios Liakopoulos and Panagiotis Gouvas, Harjula, E., Leppänen, T., Ojala, T. and Ylianttila, M.
  - "ADHT: Agent-based DHT Architecture for Constrained Devices," In: IEEE Global Communications Conference (GLOBECOM 2014), December 8-12, Austin, TX, 2014. [Accepted]

→ DHTs is a general purpose mechanism suitable for decentralized, dynamic networks.

Consistency in DHT?

- DHTs have weak consistency semantics!
  - Update can destroy data → put / get
    - Node A: put(X), node C, D stores it
    - Node B: put(Y), node C, D stores it → X is lost!
- P2P/file sharing: can live with it
  - Node A/B are often same
- Other applications may not handle it well
  - E.g., Hive2Hive / PeerBox (distributed Dropbox), user profile from 2 different machines
- Solution: introduce versions in DHTs
  - It's a bit "git" like

Versioned DHT (vDHT)!

- vDHT Goals
  - Offer better consistency semantics
  - Keep put/get operations – don't add complicated API
- "Traditional DHT API"
  - `PutState put(locationKey,data[ttl]);`
  - `Data get(locationKey);`
- vDHT API
  - `PutState put(locationKey, versionKey, data[basedOnKey(s), ttl, prepareFlag]);`
  - `putConfirm(locationKey, versionKey, ttl);`
  - `Data get(locationKey, versionKey);`
  - `List<Data> getLatest(locationKey);`

vDHT Mechanism

- Minimal internal changes
  - HashTable → SortedTable
  - put/get RPC enhanced
  - Table for unconfirmed data / tombstone for deleted data

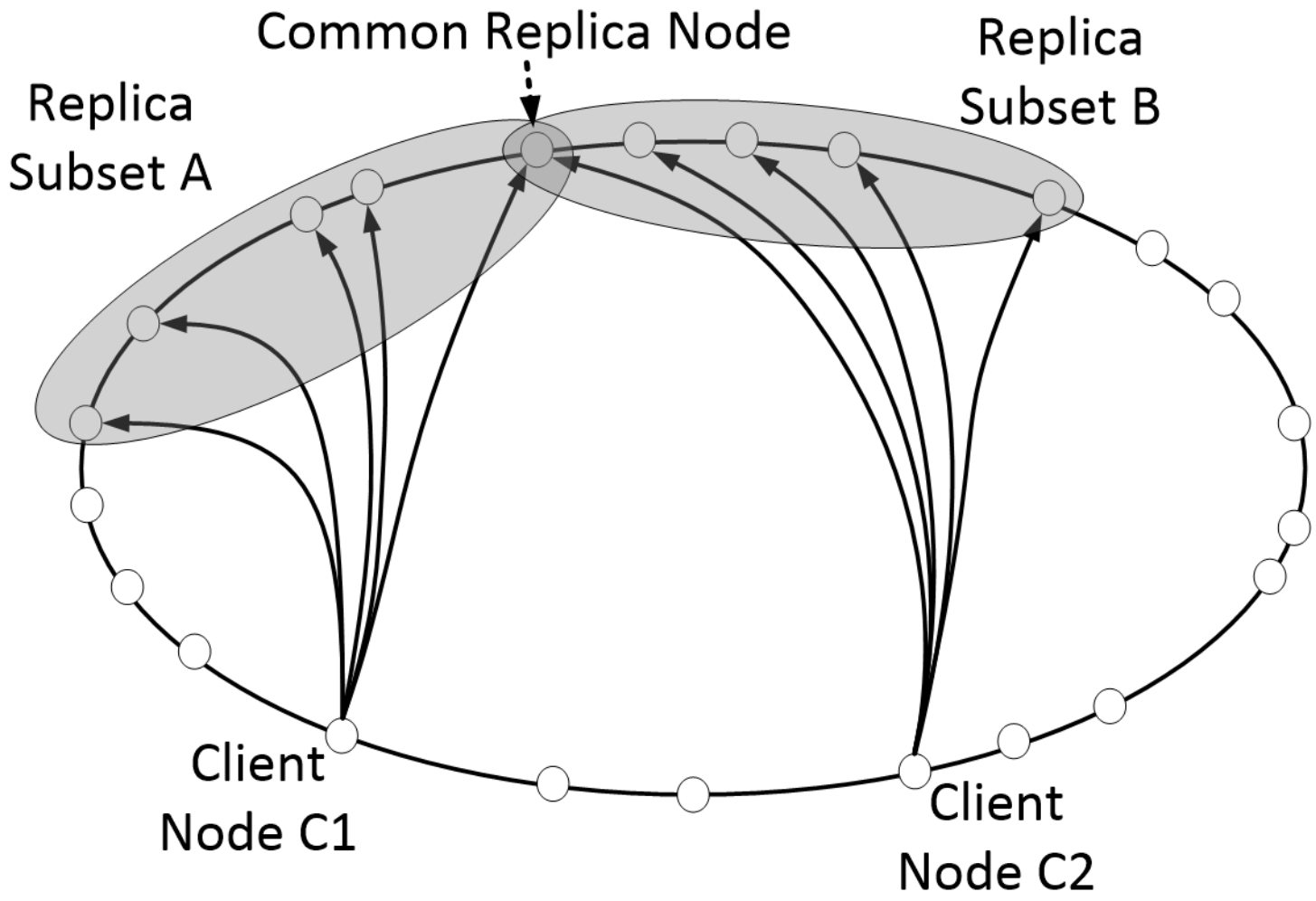
- 3 strategies implemented in TomP2P
  - Versioned put/get - increase version
  - Optimistic put - assume no conflict, if conflict, remove version
  - Pessimistic put - set prepare flag, if no conflict, commit

vDHT Pessimistic put

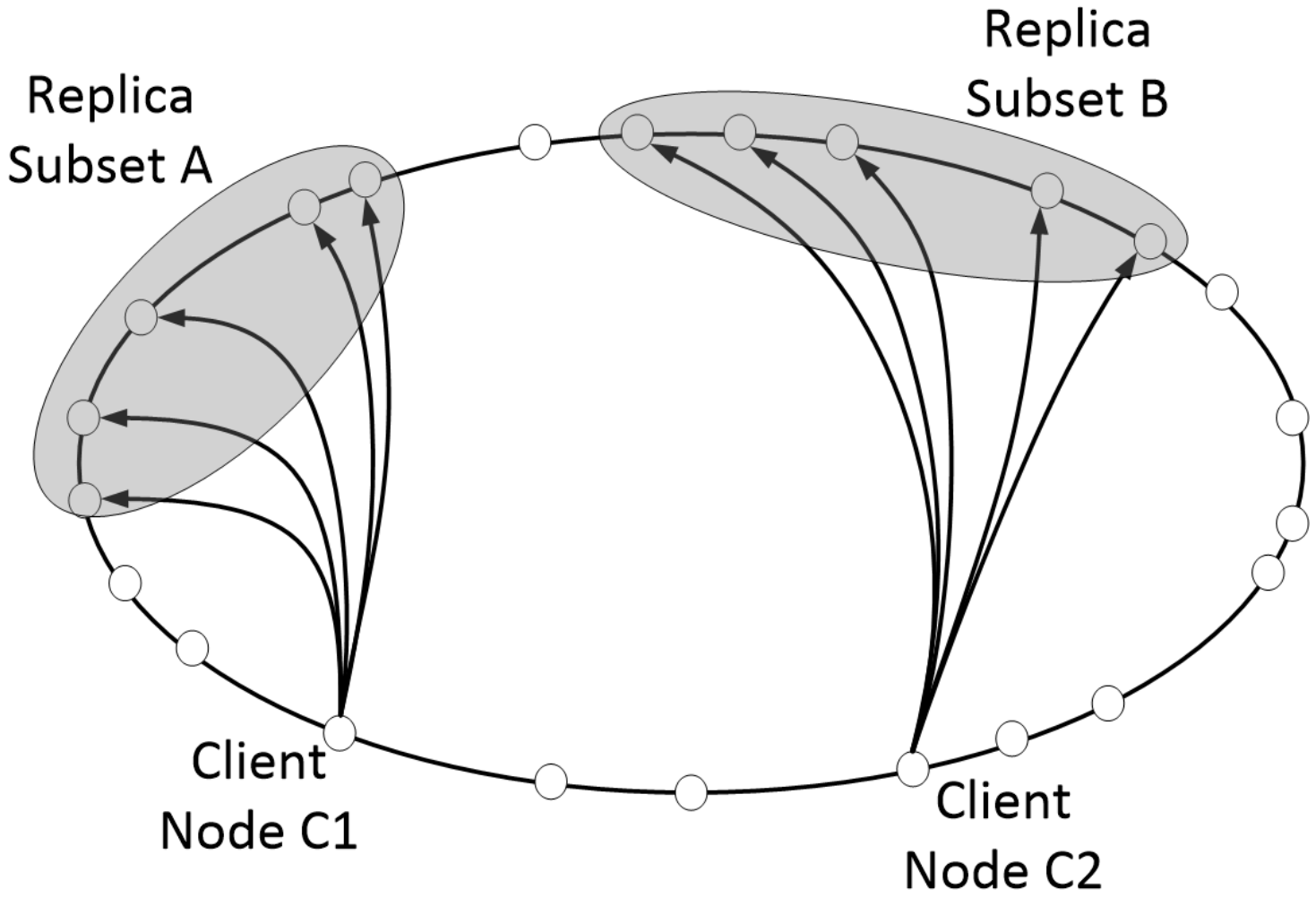
- Highest consistency semantics
  - 1. put with prepare flag, set short TTL
  - 2. put returns R results, indicating if another version exists
  - 3a. if no other version, put with commit flag, regular TTL
  - 3b. If other version, remove prepared data, get latest version, continue with step 1.) → exponential backoff

- Strong consistency in “light” churn.
- Light/heavy churn?
  - Light churn if at least one common replica peer has latest version

Light Churn Conditions

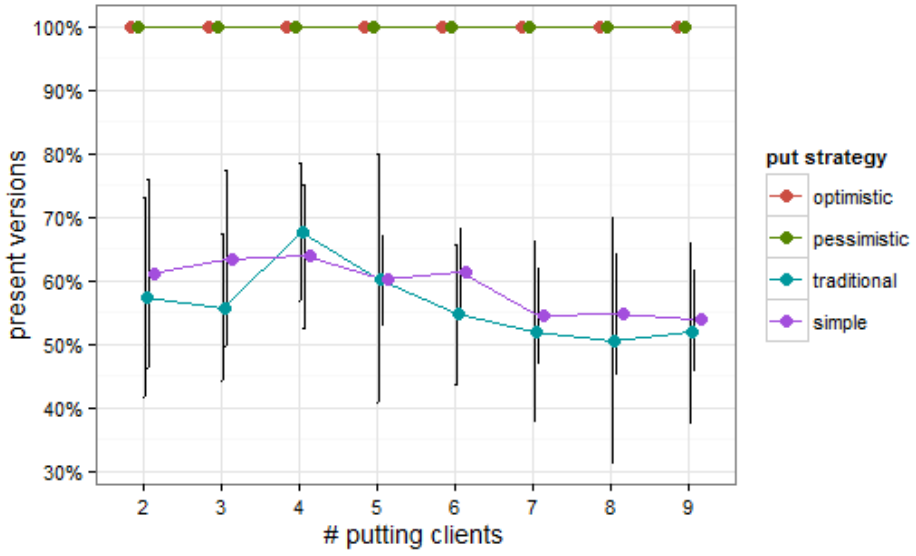


Heavy Churn Conditions

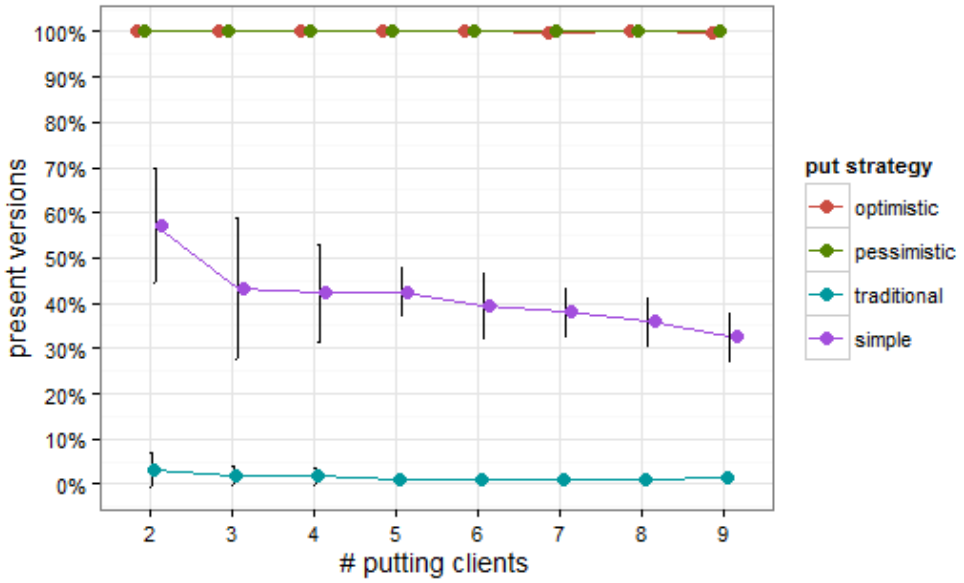


Results (1)

- No churn

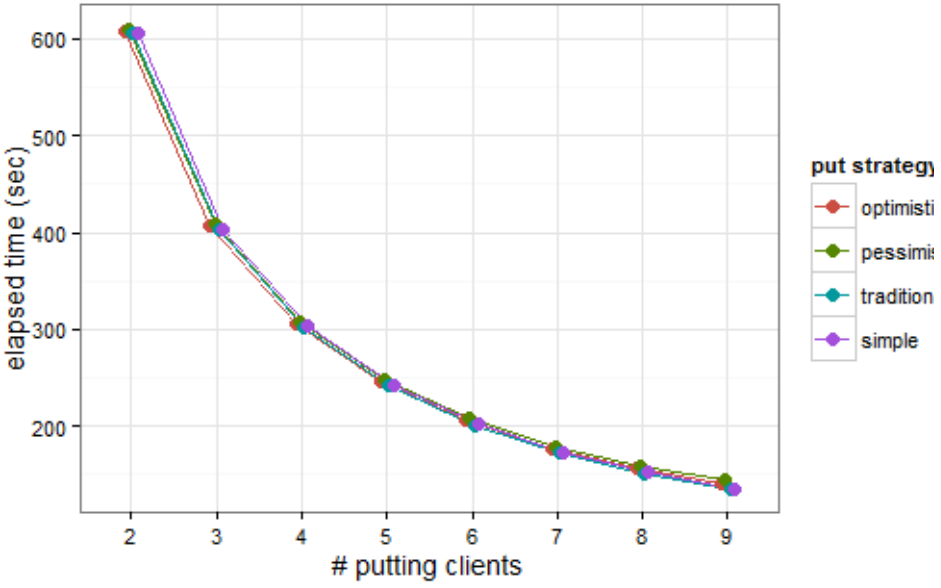


- Light churn

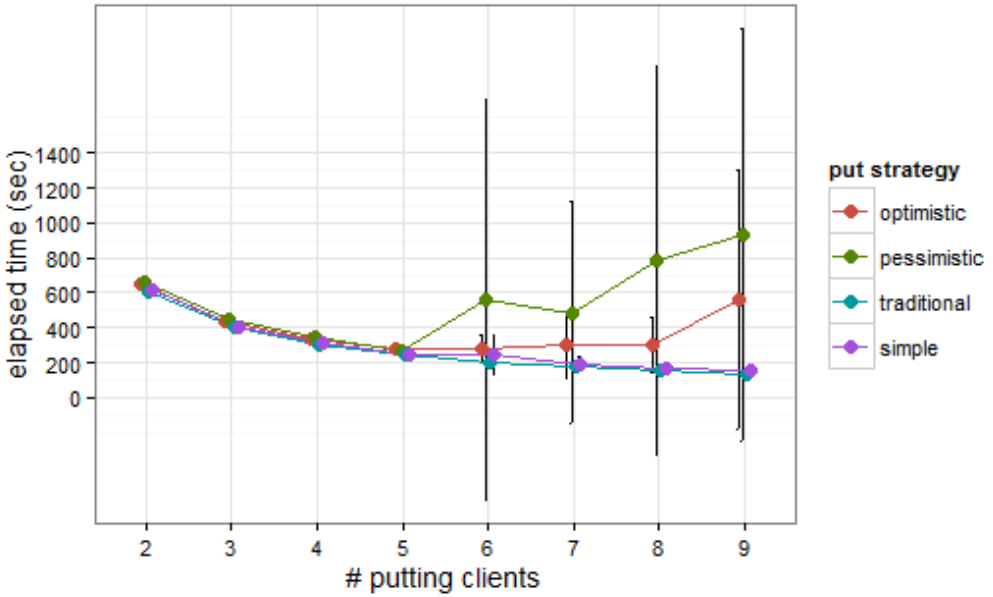


Results (2)

- Elapsed time no churn



- Elapsed time (heavy) light churn

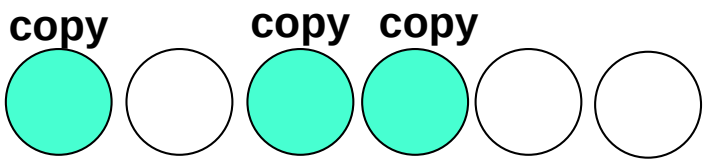


Results / Conclusions

- Consistency is not free!
  - Pessimistic takes the longest
- Works with a version history.
  - Traceability of updates; recovery of older versions; no overwrites.
- Directly integrated into DHT, no additional layer.
- No usage of timestamps, no time synchronization.
- No usage of locks, non-blocking behavior.
- Pessimistic put: light churn: consistent updates
  - Heavy churn: (manual) merging
- Number of replicas influences light/heavy churn

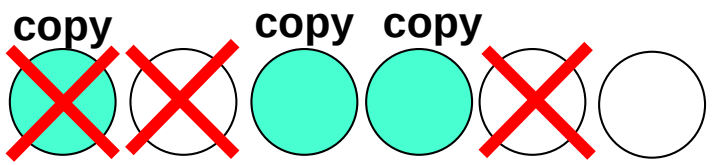
Introduction – Churn Prediction (1)

- How many replicas?
- Enough replicas are important:
  - Not to loose data in the presence of churn
  - Increases fault-tolerance and provides high data availability



Introduction – Churn Prediction (2)

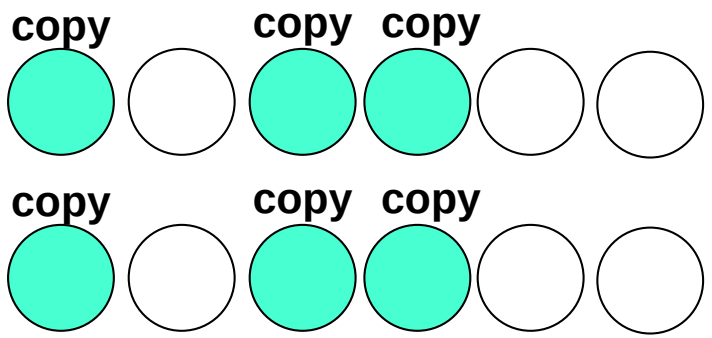
- How many replicas?
- Enough replicas are important:
  - Not to loose data in the presence of churn
  - Increases fault-tolerance and provides high data availability



- Make sure update happened under light churn
- How to determine a good replication factor?

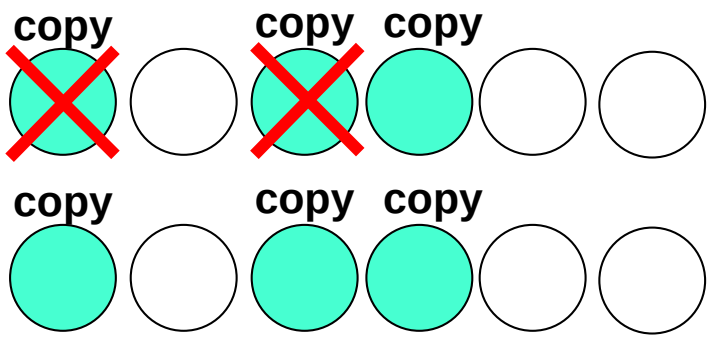
Problem Statement and Goal (1)

- Static replication factor in case the churn rate is not stable
  - if churn rate is 2, it is ok



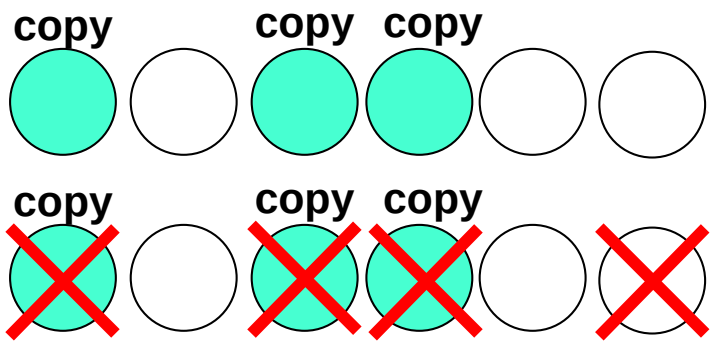
Problem Statement and Goal (2)

- Static replication factor in case the churn rate is not stable
  - if churn rate is 2, it is ok



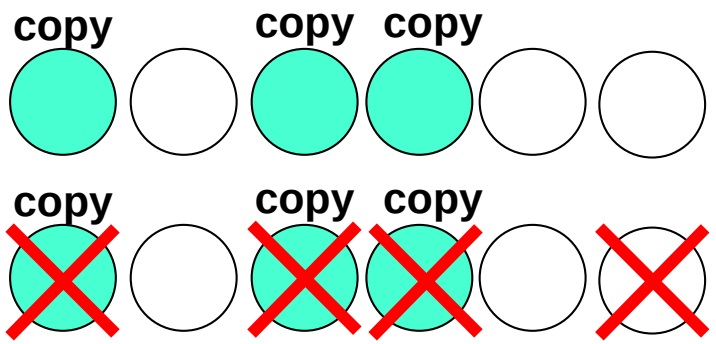
Problem Statement and Goal (3)

- Static replication factor in case the churn rate is not stable
  - if churn rate is 2, it is ok
  - if churn rate is 2-5, it is a problem



Problem Statement and Goal (4)

- Static replication factor in case the churn rate is not stable
  - if churn rate is 2, it is ok
  - if churn rate is 2-5, it is a problem



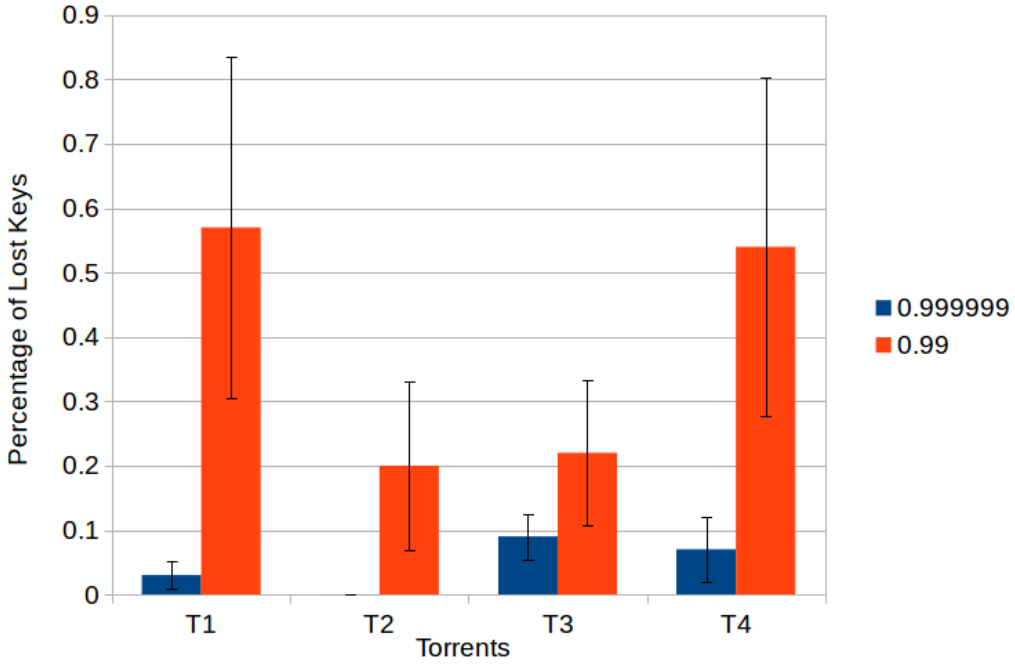
- Goal: changing the replication factor dynamically according to churn rate

Churn Prediction

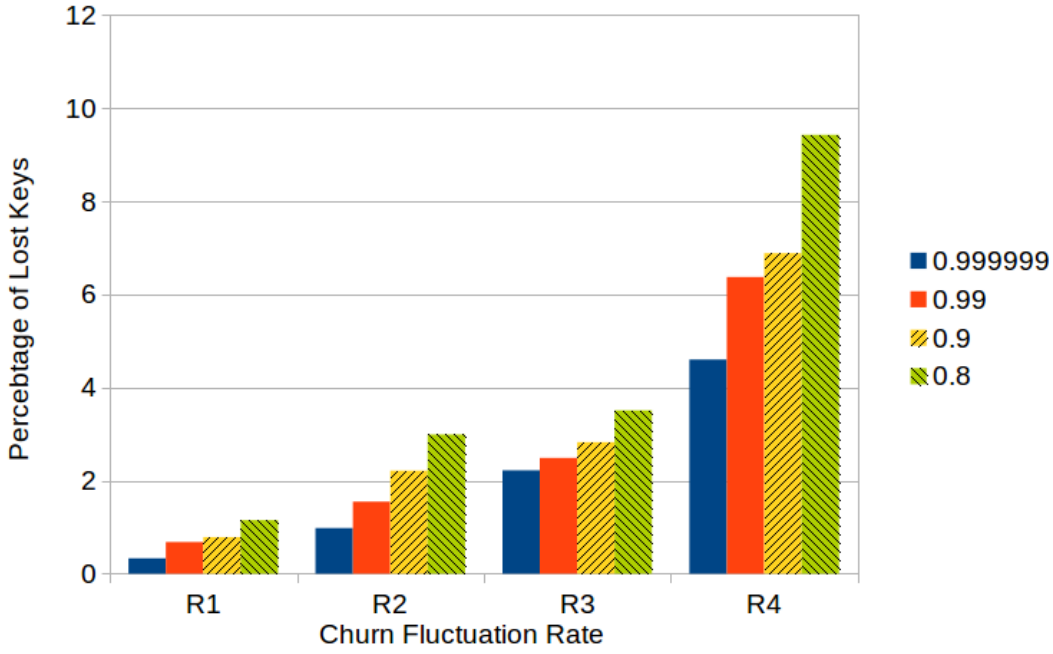
- P2P file sharing based on diurnal pattern
  - Well, what about DHTs for local clusters or IoT?
- Moving average:
  - E.g., used to define trend and make forecasts by smoothing out fluctuations (predicting stock price, forecasting GDP)
- Replication factor based on reliability (e.g., 99%) and predicted churn (EMA), for random churn
  - $\boldsymbol{r} = 0.99 = 99\%, \boldsymbol{n} = 320, \boldsymbol{k} = 40 \rightarrow$ replication factor=3
- For worst case nodes leaves (to achieve light churn), use the predicted value + x for the number of replicas
  - If prediction is correct x = 1, otherwise increase x → rf=41

Results

- Reliability Internet, data from BT



- Reliability with Synthetic data



Conclusion / Discussion

- Consistent updates in a DHT is possible with versioning
  - But only in light churn, heavy churn requires manual intervention
- To stay in light churn, correct guess of number of replicas necessary
  - Reliability is only as good as your prediction
  - EMA is used as a general purpose predictor
  - Unpredicted bursts? → increase number of replicas further

Questions?