Adaptive Plausible Clocks

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Outline

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Time, Clocks and event orderings

- Distributed system
  - N processes: $P_1, P_2, \ldots, P_N$
    - Communicate through messages
    - Asynchronous system
    - No physical clock
  - Events: send/receive message or local step
Time, Clocks and event orderings

- We want to order the events of an execution
  - Why?
    - As part of some distributed algorithm
      - E.g. Caching of replicated shared objects
      - Causally consistent multicast
    - For monitoring, debugging etc..

  - How?
    - Use a logical clock algorithm (a.k.a. time stamping system) to assign timestamps to the events
    - Timestamps
      - Equality and ordering operators: $=_{LC}$, $<_{LC}$
      - Concurrent if incomparable (unordered)
Event orderings

- **Total order**
  - No concurrency
  - Example: A < C < B < D < E

- **Causal order**
  - "happened before" or "knows about" relation
  - Example: A || C, B || C, B || D, B || E
Previous Work

- **Lamport Clocks** [Lamport 1978]
  - Total order (with tie-breaker)
    - N clock entries
    - Causal order
Previous Work

- Plausible Clocks [Torres-Rojas and Ahamad, 1999]
  - Class of logical clocks
    - Orders events consistent with causal order, but may also order concurrent events.
    - Includes: Lamport Clock and Vector clock
    - R-Entry Vector Clock
      - R clock entries
      - Clock vector indexed by Process ID mod R

![Diagram showing logical clock operations](image-url)
Non-uniformly mapped R-entry vector (NUREV) clocks

- A generalization of R-entry vector clocks
  - Allows a different mapping between process ID and clock entry in each timestamp
  - Allows (for example) self tuning and adaptation of the timestamping system
  - We have proved that All NUREV clocks are plausible clocks.
    - Regardless of mapping function and how it changes.
How to avoid information loss?

- Where is ordering information lost?
  - Inflation of one process key introduces ordering among concurrent events

Minimize inflation at updates
- Choose the mapping so that the inflation is small.

Next-Contact
- Avoid inflating the keys of processes you won’t hear from in a long time
R-Others Clock (ROV)

- **Idea**
  - Preserve recent information
  - Use exclusive entry for
    - own key
    - R-2 other processes’ keys
      (Last R-2 communication partners)
  - All other process keys share one entry

- **Benefits**
  - Constant-size timestamps
  - Agrees well with **Next-Contact**
MinDiff clock

Idea

- Minimize the inflation at each clock update
  - Use exclusive entry for own key
  - Select a new mapping function on each receive update
    - Map process keys with similar values to the same entry

- Timestamps need to include mapping
  - Small for a small number of clock entries
Experiments

- Simulations
  - Peer-2-Peer systems
  - Client-Server systems

- Performance measure
  - \#ordered concurrent event pairs / total \#concurrent event pairs
Experimental results

Accuracy compared to Vector clocks.

Peer-to-peer system  100 processes
Experimental results

Accuracy compared to Vector clocks.

Client-server system 1 server 99 clients
MinDiff timestamp sizes

Comparison of timestamp sizes

- Vector clock
- MinDiff (3 entries)
- MinDiff (5 entries)

Timestamp size (byte)

System size (#processes)
Conclusions

- Non-Uniformly Mapped R-Entries Vector Clocks (NUREV)
  - A general class of logical clocks
  - Guaranteed to be plausible
  - Includes Lamport, Vector and REV clocks

- Analysis of when and how NUREV clocks order concurrent events

- New NUREV clock algorithms
  - MinDiff and R-Others clocks
  - Improved performance at small timestamp sizes
Future Work

- Apply NUREV clocks in a group communication / ordered multicast framework
  - Work in progress
- Further investigation of mapping functions
  - Subsets with constant size representation
  - Approximations
- Bound the size of vector entries
Questions?

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