Adapting to Point Contention with Long-Lived Adaptive Safe Agreement

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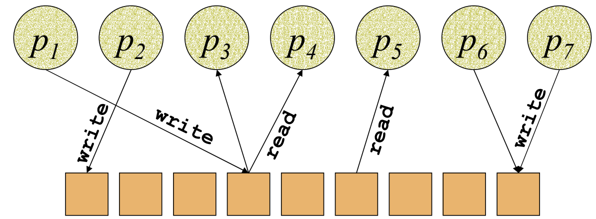
Collecting Information in Asynchronous Shared-Memory Systems



Need to collect information in order to coordinate…

When only few processes participate, reading one by one is prohibitive …

Would like to have adaptive step complexity

Adaptive Step Complexity

A function of the number of active processes

Total contention: The number of processes that (ever) take a step during the execution

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Total contention: The number of processes that (ever) take a step during the execution.

- Collect and store algorithms that are adaptive to total contention

  [Attiya, Fouren & Gafni] … [Afek & De Levie]

  - Renaming
  - Atomic snapshots

Be More Adaptive?

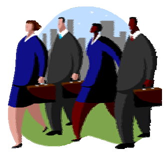
- In a *long-lived* setting…

  …processes come and go.

- What if many processes start the execution, then stop participating?

  …then start again…

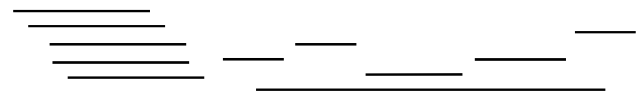
  …then stop again…



Adapting to Point Contention

- The step complexity is a function only of the number of currently active processes.

Point contention of an operation: Max number of processes taking steps together during its interval

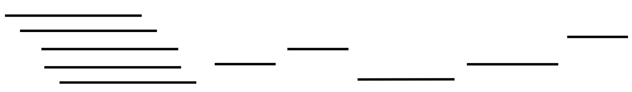


A Weaker Notion: Interval Contention

- The step complexity is a function only of the number of currently active processes

Interval contention of an operation: Max number of processes taking steps during its interval

Always larger than the point contention



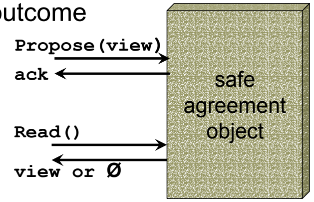
Talk Outline

- ✓ What it means to be dynamically adaptive
- How to be adaptive?
  - The safe agreement object
  - An adaptive safe agreement object
    - One-shot and long-lived
  - Adaptive renaming
  - Collecting information (adaptively)
- Extensions and connections

Safe Agreement: Specification

Separate the voting / negotiation on a decision from figuring the outcome

Two wait-free procedures: **`Propose`** and **`Read`**



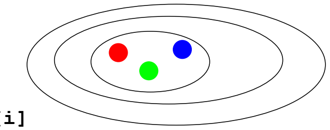
Validity of non-Ø views

Agreement on non-Ø views returned by **`Read`**

Termination: If all processes that invoked **`Propose`** return, then **`Read`** returns non-Ø view

Safe Agreement: Implementation

Use an atomic snapshot object and an array **`R`** [Borowsky & Gafni]

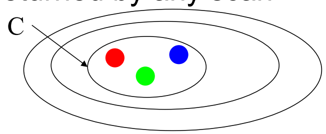


```
Propose( info )
   update( info )
   scan
   write returned view to R[i]
Read() returns view
   find minimal view C written in R
   if all processes in C wrote their view
      return C
   else return Ø
```

U U U S S U U S

Safe Agreement: Safety

Let C be the minimal view returned by any scan



Can prove that all non-Ø views are equal to C

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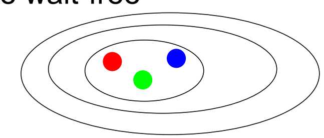
Safe Agreement: Liveness Properties

Clearly, both procedures are wait-free

- But **`Read`** may return a meaningless value, Ø



If some process invokes **`Propose`**, then after all processes that invoke **`Propose`** return, a **`Read`** returns a non-Ø value

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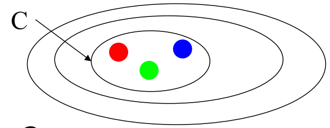
Safe Agreement: Winners

Even better...



A **`Read`** by some process in C returns a non-∅ value

E.g., the last process in C to write its view

These processes are called winners

U U U S S U U S

Safe Agreement and the BG Simulation

Safe agreement was introduced by Borowsky & Gafni for fault-tolerant simulation of wait-free algorithms

- Abstracted by Lynch&Rajsbaum

- Different interface
  - **`Propose`** and **`Read`** not separated
  - No ∅ response for **`read`**
  - Complicates the simulation

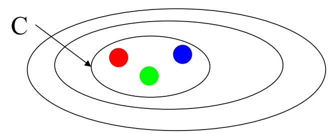
☝ They also missed an interesting feature…

[Attiya & Fouren]

Safe Agreement: Concurrency

All processes in C execute **`Propose`** concurrently

In particular, all winners



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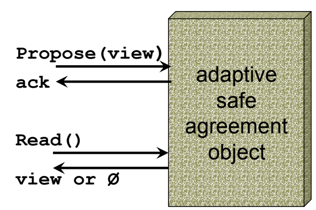
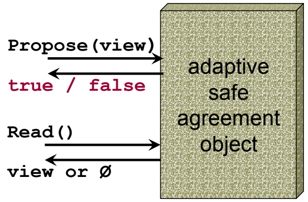


Use a doorway variable **`inside`** to avoid unnecessary update / scan

Safe Agreement: Concurrency

All processes in C execute
`Propose` concurrently

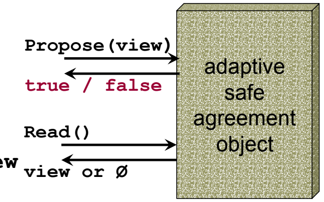
In particular, all winners



Use a doorway variable **`inside`** to avoid unnecessary update / scan

Adaptive Safe Agreement

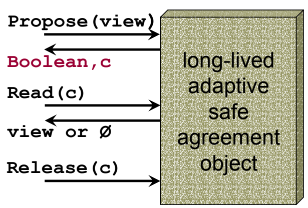
```
Propose( info )
if not inside then
   inside = true
   update( info )
   scan
   write the returned view
   return( true )
else return( false )
```



Concurrency: If a process returns **`false`** then some “concurrent” process is accessing the object

Long-Lived Adaptive Safe Agreement

Enhance the interface with a generation number (nondecreasing counter)



Validity, agreement and termination as before but relative to a single generation

Concurrency: If a process returns **`false,c`** then some process is concurrently in generation **`c`** of the object

Long-Lived Adaptive Safe Agreement

Synchronization: processes are inside the same generation simultaneously

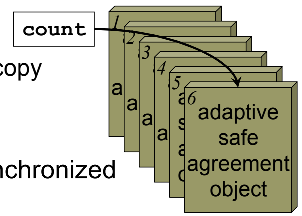
⇨ Their number ≤ point contention

⇨ Can employ algorithms adaptive to total contention within each generation

- e.g., atomic snapshots

Long-Lived Adaptive Safe Agreement: Implementation

- Many copies of one-shot safe agreement
  - `count` points to the current copy

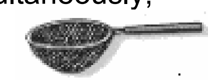


- Winners of each copy are synchronized
  - Increase `count` by 1.
  - Monotone…

When all processes release a generation, open the next generation by enabling the next copy

Catching Processes with Safe Agreement

- When processes access an adaptive long-lived safe agreement object simultaneously, at least one wins



- If a process accesses an adaptive long-lived safe agreement object and does not win, some other process is accessing the object

Good for adaptivity…

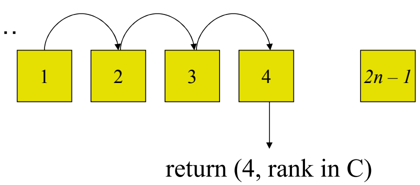
Renaming

- A process has to **`acquire`** a unique new name
  - Later **`release`** it
- The range of new names must be as small as possible
  - Preferably adaptive: depending only on the number of active processes
  - Must be at least *2k-1*

Renaming is a building block for adaptive algorithms
- First obtain names in an adaptive range
- Then apply an ordinary algorithm using these names

Renaming using Long-Lived Safe Agreement

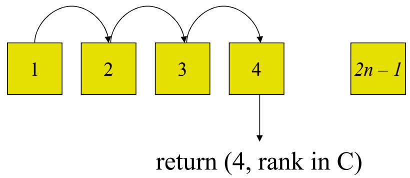
Place objects in a row…



Agreement in each long-lived safe agreement object

⇨ **Uniqueness** of names

Renaming: Complexity



Concurrency for each long-lived safe agreement object

⇨ An object is skipped only due to a concurrent process

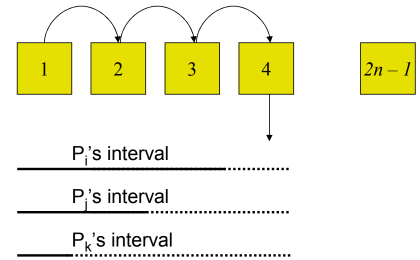
⇨ A process skips ≤ *r* objects

- *r* is the interval contention

- Range of names ≈ r^2

Renaming: Point Contention

We promised point contention



P_i skips because of P_j

⇨ P_j skips because of P_k

⇨ P_k skips because of …

They all overlap

Renaming: Name Size & Complexity

Proof is subtle since a process skips an object
either due to a concurrent winner
or due to a concurrent non-winner in C
(which it can meet again later in the row)

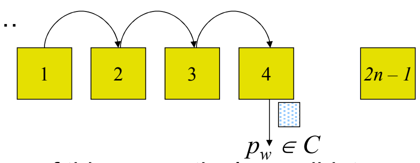
- Use a potential-function proof to show that a process skips ≤ *2k-1* objects
  - *k* is the point contention

⇨ Name ≈ k^2

⇨ *f(k)* step complexity

Store using Long-Lived Safe Agreement

Place objects in a row…



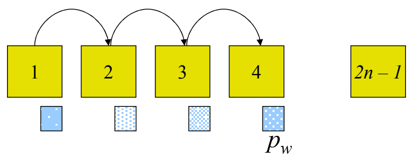
A winner *adds* the values of this generation's candidates to a register associated with the object

Agreement in each object and the synchronization property imply that the register records all values of all candidates

⇨ Across generations

⇨ Compact for specific functions / purposes

Adaptive Collect?



Go over the associated registers and read…

What if p_w and all other stores complete?

- A collect running solo still has to reach the object in which p_w has written its value!

Making the Collect Adaptive

[Afek, Stupp & Touitou, 2000]

- Before completing the store, bubble-up information the top of the array

But how?

No CAS, waiting, or locks…

Wrap-Up

- Long-lived adaptive safe agreement objects can be combined with bubble-up to obtain adaptive (to point contention) algorithms for:
  - Gathering & collecting information
  - Atomic snapshots
  - Immediate snapshots
  - *(2k-1)*-renaming (optimal)

Even More…

- The algorithms can be made fully adaptive
  - Step complexity depends on processes really participating, not just “signing in”
    - Especially relevant in renaming-based algorithms
- Can bound their memory requirements
  - But the bounds are not adaptive…

Space: The Final Frontier

- Improve the step complexity of the algorithms and reduce their space complexity
  - Lots of improvement recently for total contention
  - E.g., using randomization
- Algorithms whose space complexity is truly adaptive to point contention?
  - Currently, number of registers used depends on total contention
  - Allocated vs. used registers

Other Aspects

- Using stronger primitives (CAS…)
  - Promising for adaptive space complexity
    [Afek, Dauber, Touitou]
    [Herlihy, Luchangco, Moir]
- More modularity…
  - We made some progress with the long-lived adaptive safe agreement object
  - What about bubble-up?

Lower Bounds, Anyone?

Non-constant number of multi-writer registers is needed for adaptive weak test&set
[Afek, Boxer, Touitou]

⇨ Holds also for renaming and long-lived collect

Non-constant number of multi-writer registers is needed for adaptive generalized weak test&set
[Aguilera, Englert, Gafni]

⇨ Holds also for one-shot collect

Linear number of multi-writer registers is needed for adaptive and efficient one-shot collect
[Attiya, Fich, Kaplan]

At a Broader Perspective

Connections with recent research trends:

- Obstruction-free algorithms
  - Adapting to step contention
    [Attiya et al. DISC 2005], [Attiya et al. PODC 2006]
- Abortable / failing objects
- Population-oblivious algorithms