Time, Clocks and the Ordering of Events in a Distributed System

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Overview

This paper presents a methodology for the ordering of events in a distributed system, overcoming the significant problem of not knowing the order in which events take place in a distributed system. The paper first presents the 'happened before' relation and introduces the concept of partial ordering and its properties. These principles are then extended to the concept of logical clocks, a system to assign a numeric value to a process to determine its position in time compared to other processes. The concept of logical clocks is then used to expand the definition of partial-ordering into total ordering which unlike partial ordering, is not determined uniquely by the system of events. To illustrate the functioning of total ordering, the paper uses the example of a mutual exclusion problem. It demonstrates that each process independently simulates the functioning of the State Machine, and that synchronization is ensured by the logical clock rules.

The paper however addresses the anomalous behaviour caused in situations where one event is known to take place before another by the user, or any other entity outside the system, but the system does not know this ordering, and could present the later event as being the earlier one. To overcome this problem without putting the onus on the user, the concept of physical clocks is introduced. Physical clocks are used to assess and provide an upper bound on how out of sync the logical clocks of individual processes may become. The paper concludes by summarizing its contents and emphasizing the importance of partial ordering in any multiprocess system.

Observations of Concepts Presented in the Paper

The concept of the 'happened before' relation and the use of logical clocks to obtain a partial ordering of the events in a system is the solution to a seemingly impossible-to-solve problem. As someone new to the field of distributed systems, I cannot fully comprehend the impact that this paper has, but a glance at this paper on Google Scholar reveals that this paper has been cited a whopping 11,549 times which gives me an understanding of just how impactful the concepts in this paper are. There is a beauty in the underlying simplicity of the concept of the 'happened before' relation and logical clocks. The algorithms and the system in general make intuitive sense. These concepts have been systematically presented and have laid a solid foundation for future works.

The concept of physical clocks is similarly ingeneous. The problem it solves, i.e. the problem of anomalous behaviour is defined in concise terms. Although the proofs that serve as the pillars that hold up the functioning of physical clocks were rather complex, the purpose that the theorems serve in the larger context still feel intuitive.

This paper is not without its drawbacks, but by and large they are all addressed in the paper, either explicitly or implicitly. For example, the lack of consideration for failures in the system is brought up and stated to be beyond the scope of the paper. It is my understanding that the highly theoretical

nature of the paper, best illustrated by the mutual exclusion example, which would be too impractical and unwieldy in a real-world context, is intentional on the part of the author even though it is never explicitly stated anywhere.

However, relating to the mutual exclusion example, a potential drawback/point of discussion for me is this: is the total ordering of events obsolete, or not as useful as partial ordering. The paper's own conclusion emphasizes the importance of partial ordering in a multiprocess system and partial ordering is repeatedly stated to be entirely determined by the system in contrast to total ordering. The example used to illustrate it, although intentionally theoretical, for me seems to underscore its lack of applicability in real-world settings. Additionally, from the material covered in class, I now know that logical clocks laid the groundwork for vector clocks, a system that optimizes the use of information and serves as a more effective way to obtain the 'big picture' of the current functioning of the system. I wonder then, if it would be fair to say that total ordering by logical clocks is outdated or obsolete

Other Observations about the Paper

I appreciate the clear and concise nature of the paper. The definitions are all unambiguous and the rules and principles of the algorithms are stated clearly. The sequence of concepts presented in the paper is structured well. Each concept ties into the next one extremely well. I appreciate that the proofs for the physical clocks section were placed in an appendix, since had it been in the section proper, it would have made that topic seem more opaque, and broken the flow of the explanation of the concept.

The paper uses several explanations and diagrams to illustrate key concepts, which made grasping them a much simpler process. I'm especially grateful for the example that explains the anomalous behaviour concept, which I feel succinctly captures the reason for and outcome of that process.

Similar to the other paper that Leslie Lamport co-authored that I read for this assignment, this paper contains, in my opinion, atypically few citations. But unlike in the other paper where I felt like it highlighted both the positives and drawbacks of the paper, it's my opinion here that Lamport clearly intended the paper to be theoretical in nature, and the handful of citations shows how original and groundbreaking this work is. That is not to say that papers with a large number of citations are derivative and unoriginal; but even before reading this paper I was aware of how groundbreaking and influential this paper is, and seeing the four citations at the end of the paper only served to confirm that fact.

One last observation that I'd like to make is that in my opinion, the concept of physical clocks came across as dense and much more difficult to follow than the previous sections. This might simply be a personal observation, since I have been familiar with the concept of logical clocks for a few weeks now, but have known about physical clocks for much less time. It could also be the heavy reliance on theorems and bounded values in this section. This isn't a drawback, in my opinion, but an observation.

Conclusion

This paper presents a way to order events in an asynchronous distributed system both partially and totally, with the help of the ‘happened before’ relation. Although highly theoretical, its clear and concise stating of its algorithms serve as a solid foundation for future works to overcome the limitations present in this paper