Working document:
Logical Clocks and Distributed Testing: Some Related Work

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1 Introduction

Distributed systems are reactive systems that interact with their environment at several physically distributed interfaces, called ports. The classical approach to testing such systems involves placing a local tester at each port.

Algorithms to control distributed systems are defined and adapted following communication mechanisms and synchronization of processes which execute in a parallel way. Those processes may execute in different sites and may cooperate between each other. Yet, an algorithm is announced as distributed if it is executed concurrently, with separate parts of the algorithm being run simultaneously on independent processors, and having limited information about what the other parts of the algorithm are doing.

Defining a distributed algorithm running on a distributed system requires to define a global and coherent time for all working processes. Indeed, local processes of a distributed system are cadenced by different local clocks. To ensure a reliable exchange of messages between processes, one have to whether synchronize local clocks with a reference clock or define a logical time.

Knowing that it is difficult to synchronize local clocks, existing works propose to explore logical clocks concept in order to define techniques in testing distributed systems. In addition, the concurrent nature of local processes of a distributed systems involves a state space explosion problem especially when testers deal with algorithms to control this kind of systems. This paper surveys some related work in exploring virtual time to introduce formal approaches in distributed testing.

2 Related work

Model-based testing (MBT) is a process in which test automation is based on a model representing a specification or some aspects of the *system under test (SUT)*[6]. Related works in distributed testing explored MBT and defined several formal approaches and techniques. Some of those approaches used logical clocks[7, 3, 2], to define a virtual time for scheduling events.
The following is a brief survey of some related papers on testing distributed (concurrent) systems using logical clocks:

- In Paper[9], Myungchul Kim, Samuel T. Chanson, Sungwon Kang and Jaehwi Shin studied the problem of testing concurrent distributed systems as blackboxes modeled as *asynchronous communicating finite state machines (ACFSMs)*. The authors defined and presented with illustrative examples an approach to derive test cases in a formal way for concurrent distributed systems. The approach of the paper defined techniques to avoid the state explosion problem by introducing a *causality relation model* based on logical clocks advancing mechanism. By adopting a causality relation model, the authors of this paper expressed a true concurrency model and hence avoided classical approaches in distrusted testing that use interleaving methods for the events in a concurrent system. Paper[9] introduced the *Minimal Causality Path (MCP)* using logical clocks as global event sequence with minimal length. Those paths were later used in test case generation in order to avoid the state space explosion problem. The paper also introduced for the first time new definitions such as *Observationally Rate (OR), Stable State (SS)* and *Controllability Rate (CR)*. Yet, the authors in the paper assumed that atomic actions in the model consume exactly one unit of logical time, hence, the model cannot be considered as applicable to the real world situations.

- In Paper[10], Myungchul Kim, Samuel T. Chanson, Sungwon Kang and Jaehwi Shin extended previous work presented in Paper[9] by relaxing the unit-time assumption to any natural or real numbers in describing timing constraints and by presenting a computationally efficient algorithm for deriving test cases from the model with respect to the relaxed event duration assumed previously.

- In Paper[11], Young Joon Choi, Hee Yong Youn, Soonuk Seol and Sang Jo Yoo proposed a test sequence generation algorithm in a formal way using logical clocks. Their work aims to solve both controllability and observationally problems occurred in distributed testing with concurrent events. The proposed algorithm is generic and can be used for any possible communication paradigm. Authors of the paper took benefit from the use of logical clocks and hence they can make difference between concurrent events and causal ones by labeling and comparing the logical clock values of the events of a so-called *test sequence (TS)*.

In this new approach, the local testers generate additional signals to control concurrent events when these last can be identified. Using reachability tree generation techniques, the authors demonstrated that the proposed algorithm can solve the so-called *contro-observation problem* in a formal way.
This work propose a new test architecture for solving the latter problem. A Specification and Description Language (SDL) tool is used to verify the correctness of the proposed algorithm. Yet, authors applied their algorithm to the message exchange for the establishment of Q.2971 point-to-multipoint call/connection[1] as a case of study.

- In paper[4], Hernan Ponce-de-Leon, Stefan Haar and Delphine Longuet extended the **ioco** conformance relation to test concurrent distributed systems specified with true concurrency and hence they defined the **co-ioco** conformance relation. In Paper[5], The authors assumed that global observation in distributed testing cannot be reconstructed from local observations made in local interfaces of a distributed system. Hence, they proposed to use vector logical clocks as defined in Paper[3, 2] in order to regain global conformance from local testing. In this work, authors presented a framework which only considers synchronous communication for concurrent systems specified; for a first time; as network of *Labeled Transition systems (LTSs)*; and then as one distributed *Petri net*. An adaptation of the previous test generation algorithm for **co-ioco** for handling vector timestamps was presented in this work.

Summary Table 1 synthesizes the aspects of previous related works together with the approach presented in Paper[1] and that we intend to extend using logical clocks in contrast to related work.

[1]In telecommunications, point-to-multipoint communication is communication which is accomplished via a distinct type of one-to-many connection, providing multiple paths from a single location to multiple locations[8].

Paper	**Specification model**	**Nature of communication**	**Test assumptions**	**Objectives**
Paper[9]	Communicating Finite State Machines	Asynchronous	SUT as blackbox Logical time Events durations of one time unit	Avoid state space exposition problem
Paper[10]	Communicating Finite State Machines	Asynchronous	SUT as blackbox Logical time Events durations relaxed to any natural number	Avoid state space exposition problem
Paper[11]	Communicating Finite State Machines	Synchronous	SUT as blackbox Logical time Events durations of one time unit	Solve the contro-observation problem Make test results reproducible
Paper[5]	Labeled transition Systems and Petri nets	Synchronous	SUT as blackbox Logical time Events durations of one time unit	Regain global conformance from local testing
Paper[1]	Timed Input Output Labeled transition Systems	Asynchronous	SUT as graybox Physical time Events durations relaxed to any natural number	Testing local subsystems Testing of internal communication

Table 1: Summary table of previous related works aspects.

3 Conclusions and future work

We have presented a brief survey of some related papers on testing distributed and concurrent systems with different communication protocols and using logical clocks. Our future work aims at testing distrusted systems specified as *timed input output transition systems (TIOTSs)* with asynchronous communication using logical clocks based on the approach presented in Paper[1] and which splits distributed testing into two parts:

- Conformance testing for local subsystems with respect to their TIOTS models.
- Testing of internal communications.

By detecting concurrent events from causal ones, our future approach aims to avoid the state exposition problem occurred when considering all configurations of interleaving emissions and receptions of the distributed system.

References

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