A Systematic Study on the Difference and Conversion Between Synchronous and Asynchronous Protocols

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Background

• **Distributed systems**: A network of $n$ users that communicate by sending messages to each other.

• **Synchronous systems**: Delivery-time-bounded systems where each user can access the global clock with zero delay.

• **Asynchronous systems**: Systems in which users only have access to local clocks and messages are not bounded.
Last Year’s Work

• Find a distributed systems model similar to the real world
• Aimed to combine synchronous and asynchronous models
• Created an adversary that got close to the goal
## Motivation and Goal

<table>
<thead>
<tr>
<th>Model</th>
<th>Practical</th>
<th>Efficient</th>
<th>Simple</th>
</tr>
</thead>
<tbody>
<tr>
<td>Synchronous</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Asynchronous</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

Developers need a method to create less complex protocols that work on real systems.

**Goal**

Identify conditions under which a synchronous protocol can be converted to an asynchronous protocol.
Equivalence of Protocols

A distributed protocol can be understood as a function $P(i)$ where $i$ is an input vector containing the input messages for each user. The protocol creates an output vector $o$ that specifies the output generated by each user. Two protocols are equivalent if their output vectors are identical.

General Algorithm

\[
P(i) \rightarrow o \\
P'(i) \rightarrow o'
\]

$o = o'$

Distributed Algorithm

\[
P(i, \alpha) \rightarrow o \\
P'(i, \alpha') \rightarrow o'
\]

$\forall i, \alpha \exists \alpha' \exists o = o'$
Clock in Asynchronous Model

We begin by analyzing the impact of the “global clock” part of the synchronous model. To do this, we add a global clock to the asynchronous model, and observe how that effects the users.

Result
An asynchronous model with a global clock is equivalent to the plain asynchronous model

Therefore, the global clock alone does not add synchronicity to the asynchronous model.
Redefining Protocols

To improve the simplicity of defining protocols, we prove the following:

• Time-based synchronous model = Round-based synchronous model (known)
• Any protocol can be described as a sequence of events

The event-order-based description of the protocols makes it much easier for us to prove equivalence, and makes it easier to define adversaries
Adversary in Synchronous Model

• A **normal adversary** can corrupt up to \( f \) users, and allows them to send any arbitrary message at any time.

• A **special adversary** can, in addition to the effects of the normal adversary, block up to \( f \) messages from other users.

Result

A synchronous system with a special adversary is equivalent to an asynchronous system with a normal adversary.
Equivalence Results

- Asynchronous
- Asynchronous + Global Clock
- Time-based Synchronous
- Round-based Synchronous
- Asynchronous + Normal Adversary
- Synchronous + Special Adversary

New

Known
Hierarchy Results

Our research along with our special adversary provide us with a method to order distributed system models based on how restrictive they are:

- Asynchronous
- Async + Normal
- Sync + Normal
- Sync + Special
- Synchronous

This allows for more precise navigation of synchronicity in distributed systems overall.
Conclusion

• We determined the extent of the effect of the main restrictions on distributed systems
  • Global clock
  • Time-bounded delivery

• Our special adversary combined with the synchronous system acts as a structured model to create simpler protocols
  • Allows for transformation between synchronous and asynchronous protocols

• Our hierarchy allows developers to precisely alter the synchronicity of their models to accurately simulate any distributed system
Future Work

• Can we retain the model hierarchy after removing the normal adversary?
• Does the normal adversary effect the efficiency of users in the asynchronous model?
• Can we generalize adversary effects to create models of any arbitrary strength?
• Other than the protocols we have already tested, which other distributed systems protocols can be converted to synchronous or asynchronous given our models?
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Bibliography


