Virtual Synchrony

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Review

- Multicast
- Causal and total ordering
- Consistent Cuts
- Synchronized clocks
- Impossibility of consensus
- Distributed file systems

Goal

- Distributed programming is hard
- *What tools can make it easier?*
- *What assumptions can make it easier?*

Distributed programming is hard!
Let's go shopping!!!

According to http://en.wikipedia.org/wiki/Barbie,
Barbie once said "Math is hard!" (misquoted).

The Process Group Approach to Reliable Distributed Computing

- Ken Birman
  - Professor, Cornell University

- ISIS
  - “toolkit mechanism for distributed programming”
  - Financial trading floors
  - Telecommunications switching

Virtual Synchrony

- Simplify distributed systems programming by assuming a ***synchronous environment***
- Features:
  - Process Groups
  - Reliable Multicast
  - Fault Tolerance
  - Performance

Outline

- Problem / Motivation
- Solution (Virtual Synchrony)
  - Assumptions
  - Close Synchrony
  - Virtual Synchrony

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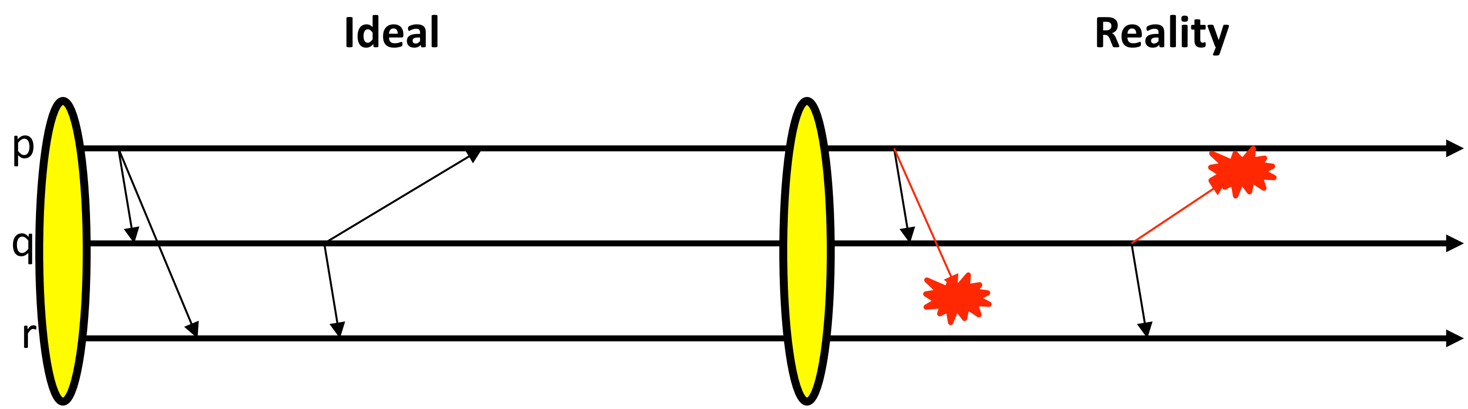
Motivation

- Distributed Programming is hard

Difficulties

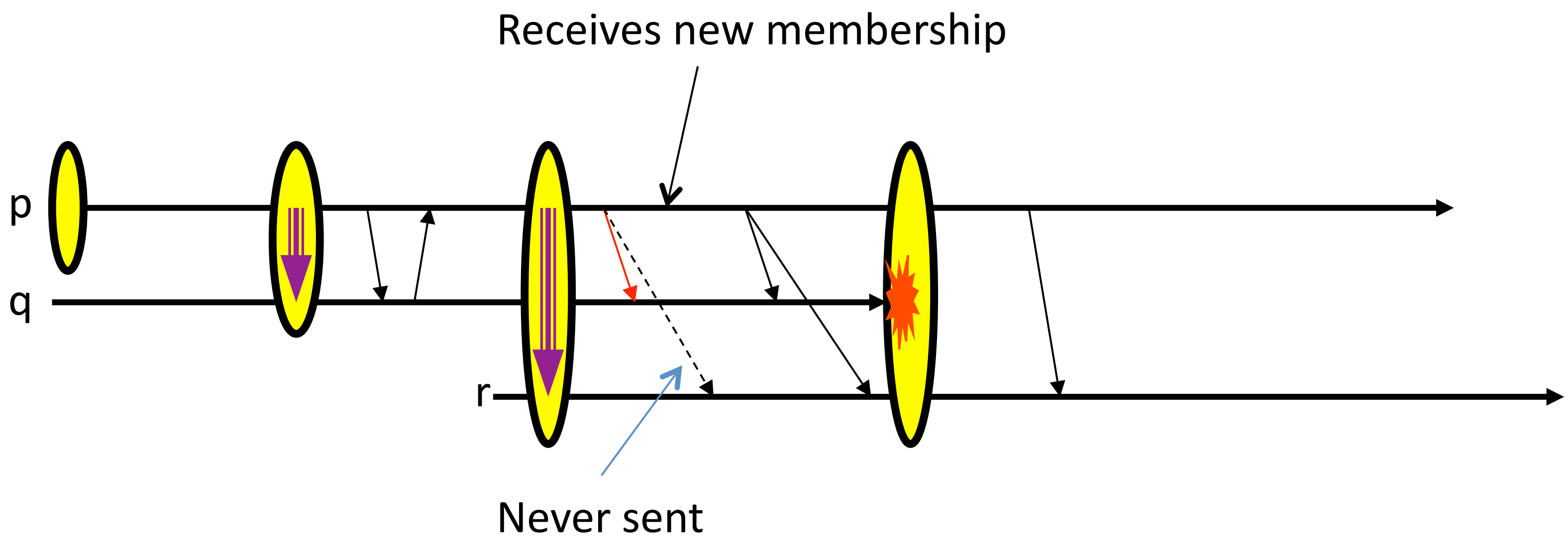
- No reliable multicast
- Membership churn
- Message ordering
- State transfers
- Failure atomicity

No Reliable Multicast



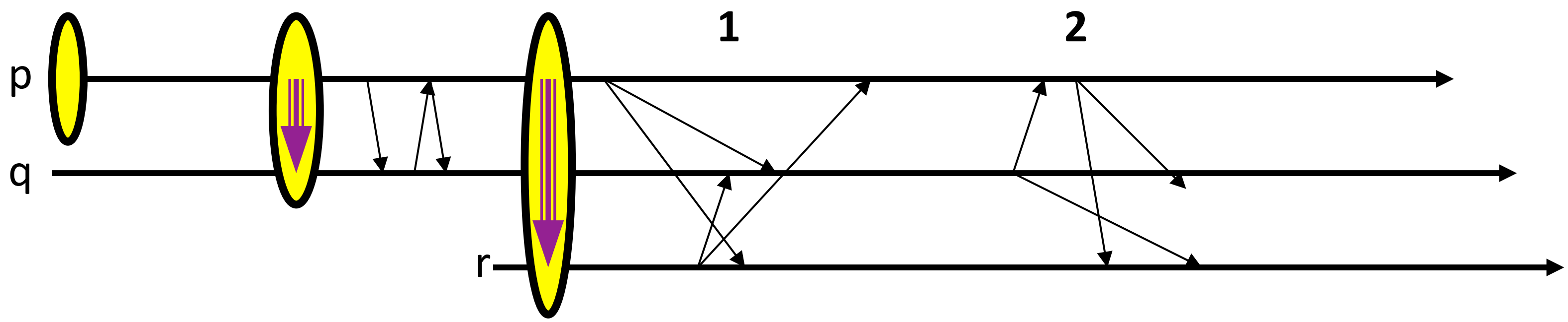
- UDP, TCP, Multicast not good enough
- *What is the correct way to recover?*

Membership Churn



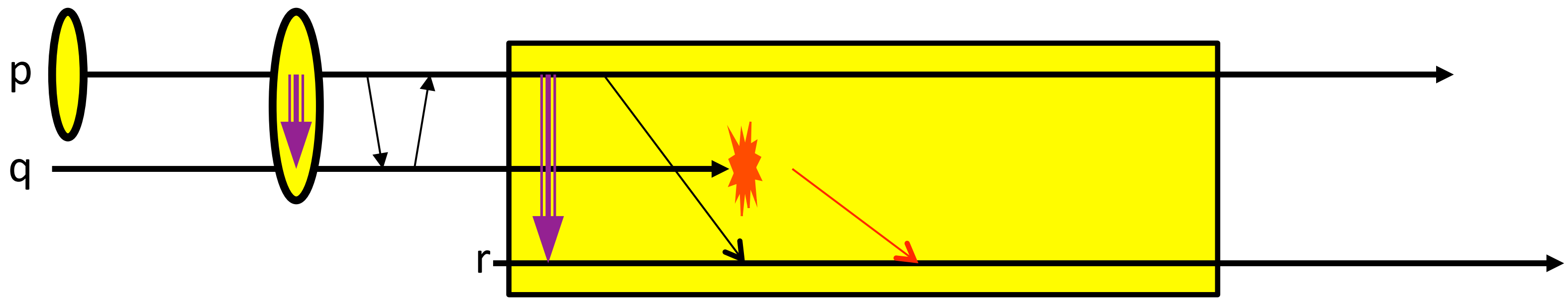
- Membership changes are not instant
- How to handle failure cases?

Message Ordering



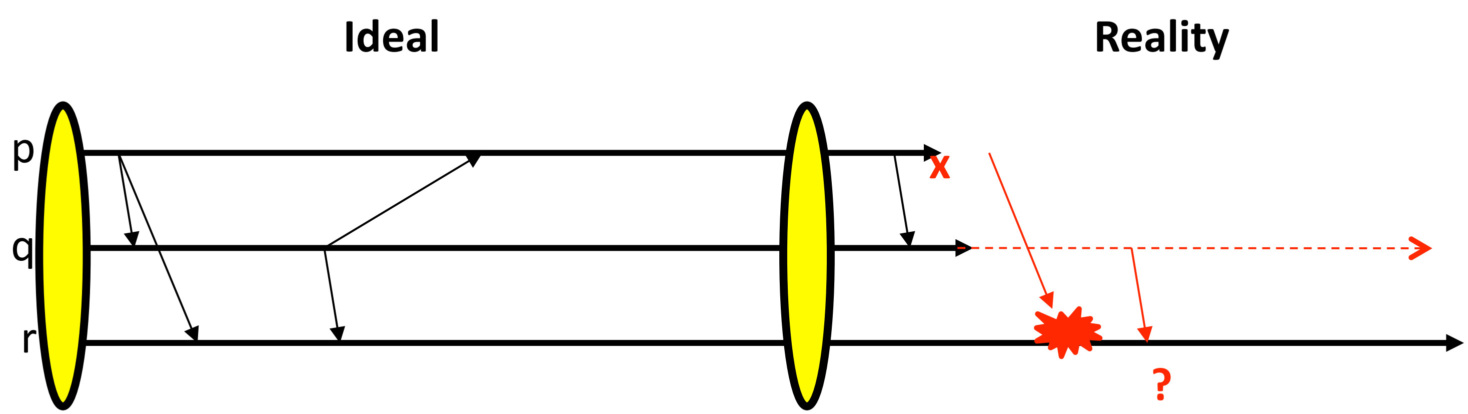
- Everybody wants it!
- How can you know if you have it?
- How can you get it?

State Transfers



- New nodes must get current state
- Does not happen *instantly*
- How do you handle nodes failing/joining?

Failure Atomicity



- Nodes can fail mid-transmit
- Some nodes receive message, others do not
- Inconsistencies arise!

Motivation Review

- ***Distributed programming is hard!***

- No reliable multicast
- Membership churn
- Message ordering
- State transfers
- Failure atomicity

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Assumptions

- WAN of LANs
- Unreliable network
- Flow control at lowest layer
- Clocks not synchronized
- ***No partitions***
  - *CAP Theorem?*

Failure Model

- Nodes crash
- Network is lossy
- Can’t distinguish difference

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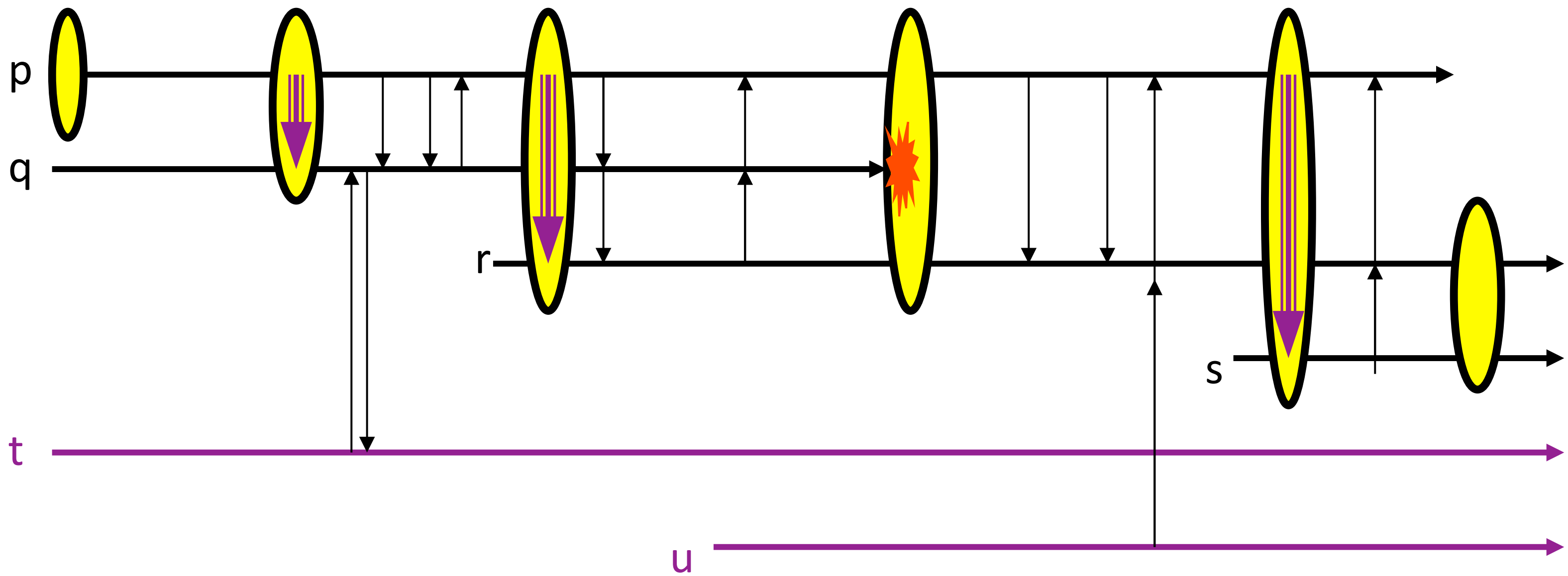
Outline

- Problem / Motivation
- Solution (Virtual Synchrony)
  - Assumptions
  - Close Synchrony
    - Model
    - Significance
    - Issues
  - Virtual Synchrony

Model

- Events (all ~~or nothing~~)
  - Internal computation
  - Message transmission & delivery
  - Membership change

Model



- ***Synchronous*** execution

Significance

- Multicast is always reliable
- Membership is always consistent
- Totally ordered message delivery
- State-transfer happens *instantaneously*
- Failure Atomicity
  - Multicast is a *single event*

Issues

- Discrete event simulator
- Is it practical?
- Impossible with failures
- Very expensive
  - System progresses in lock-step
  - Limited by speed of other members

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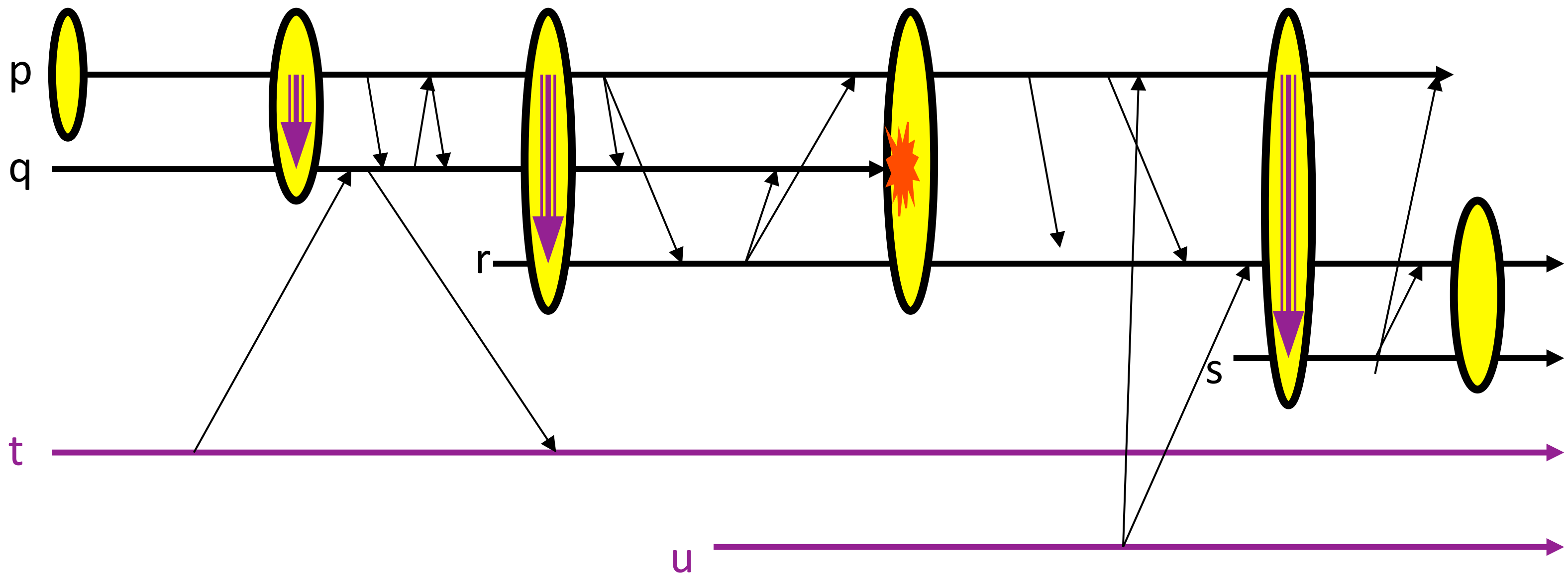
Outline

- Virtual Synchrony
  - Asynchronous Execution
  - Virtual Synchrony
  - ISIS
  - Parallels
  - Benefits
  - Discussion

Asynchronous Execution

- Key to high throughput in distributed systems
- Only wait for responses (or too fast sends)
- Communication channel
  - Acts as a pipeline
  - Not limited by latency
- Not possible with Close Synchrony!!

Asynchronous Execution



Virtual Synchrony

- Close Synchrony + Asynchronous
- Indistinguishable to application
- So….when can synchronous execution be relaxed?

ISIS

- Communication Framework
- Membership Service
- VS primitives
  - ABCAST
  - CBCAST

ISIS

- Problem
  - *Crash and Lossy Network Indistinguishable*
- Solution:
  - Membership list
  - Nonresponsive or failed members are dropped
  - Only listed members can participate
  - Re-join protocol
  - *Does Membership exist in all distributed systems?*

ISIS

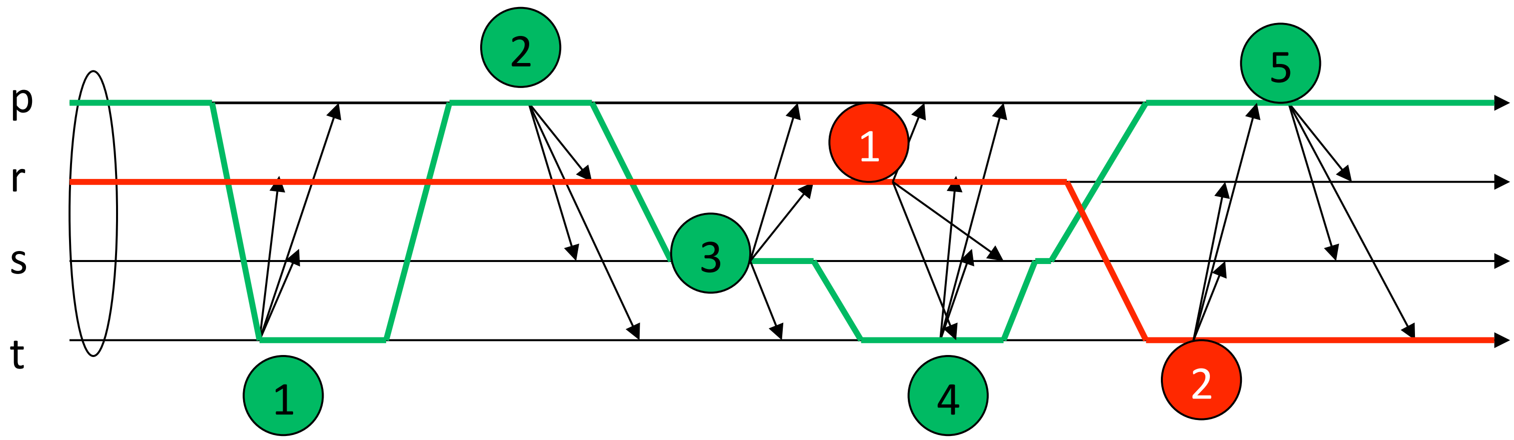
- Atomic Broadcast (ABCAST)
- No message can be delivered to any user until all previous ABCAST messages have been delivered
- Costly to implement
- …But not everyone needs such strong guarantees

ISIS

- Causal Atomic Broadcast (CBCAST)
- Sufficient for most programmers
- Concurrent messages commute
- Weaker than ABCAST

When to use CBCAST?

Each thread corresponds to a different lock



- When any conflicting multicasts are uniquely ordered along a single causal chain
- .....This is Virtual Synchrony

Parallels

- Logical time
- Replication in database systems
- Schneider's *state machine approach*
- Parallel processor architectures
- Distributed database systems

Benefits

- Assume a closely synchronous model
- Group state and state transfer
- Pipelined communication (async)
- *Single event* model
- Failure handling

Discussion

- **Partitions**
- False positives
  - Most have them, VS admits it
- False negatives
  - Depend on a timeout

Summary

- Programming in distributed systems is hard
- Close Synchrony makes it easier
  - Costs too much
- Take asynchronous when you can
- Virtual Synchrony
  - Pipelined
  - Easy to reason over

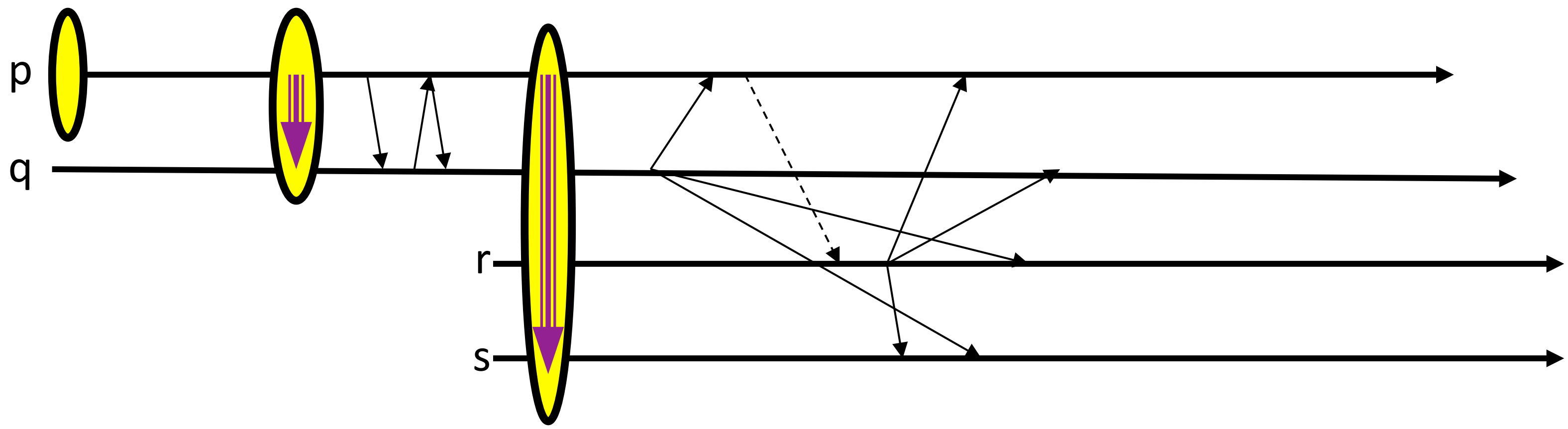
Understanding the Limitations
of Causally and Totally Ordered Communication

- Authors
  - David Cheriton
    - Stanford
    - PhD – Waterloo
    - Billionaire
  - Dale Skeen
    - PhD – UC Berkeley
    - 3-phase commit protocol

The flaws of CATOCS

- Unrecognized causality
- No *semantic* ordering
- No Efficiency Gain (over State-level Techniques)
- No Scalability

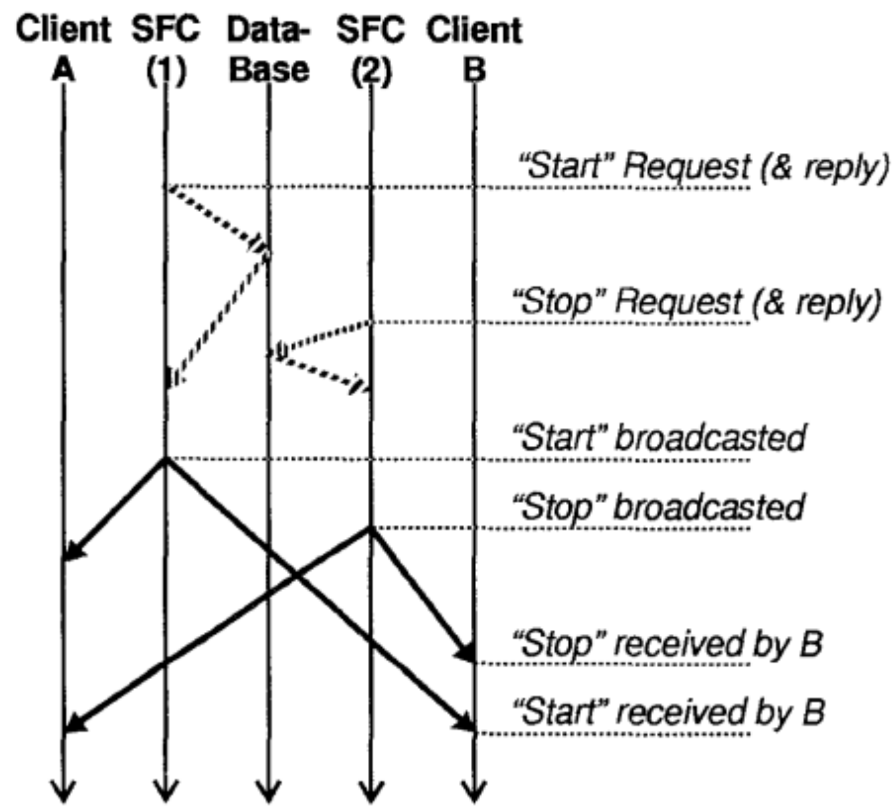
Unrecognized Causality



- External communication is unknown

Unrecognized Causality

- Database is external entity
- Causal relation exists, but CATOCS misses it



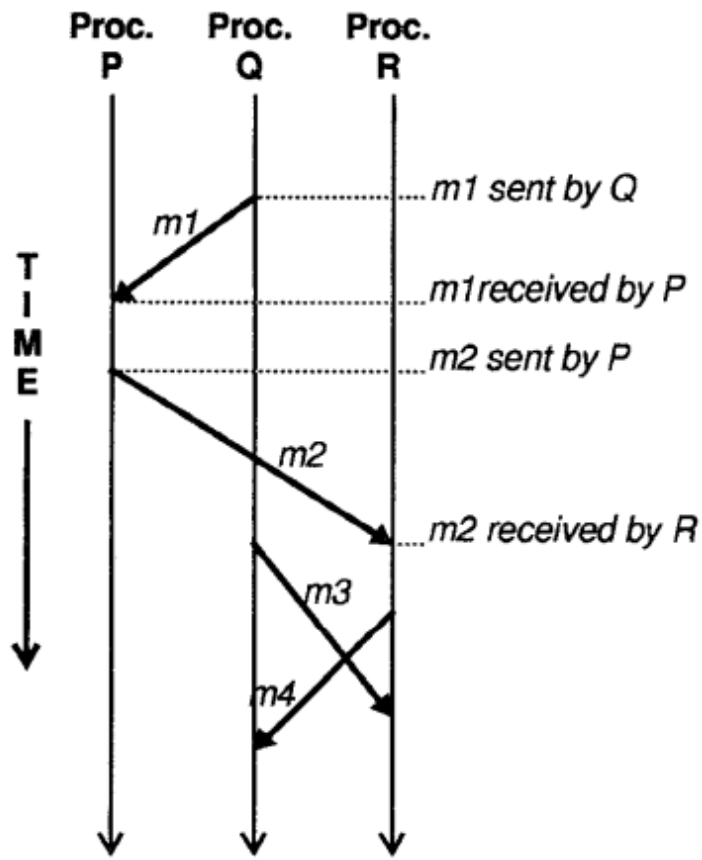
No Semantic Ordering

- Serialization
  - Messages can't be "group together"
  - Implementing eliminates CATOCS need
- Causal Memory
  - Solution: state-level logical clock

No Efficiency Gain

- Still need state-level techniques
- False causality
  - Reduces Performance
  - Increased Memory
- Message overhead

No Efficiency Gain



- What if m2 happened to follow m1, but was not causally related?
- CATOCS would make ***False Causality***

No Scalability

- ≈ quadratic growth of expected message buffering
- Rebuttal:
  - Worst case
  - Impractical use case

Summary

- CATOCS software is overkill
- Communication system doesn't know everything
- Everything is better at the application level

Conclusions

- Distributed Programming is hard
- Close Synchrony
  - Too costly
- Virtual Synchrony
  - Limitations
- VS not perfect for all situations