CS514: Intermediate Course in Computer Systems

Lecture 23: March 14, 2003

Consistency issues in failure handling

TCP Streams

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- One week ago we very briefly saw how TCP overcomes failures
- TCP is the workhorse of the Internet
  - This is because TCP is a “good citizen”
  - Until recently, every web operation used its own TCP connection!
- Today: look at one aspect of TCP failure handling in more detail
  - In what sense is TCP more reliable than UDP?

Dealing with failures

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- Packets lost, duplicated, out of order: easy, just use sequence numbers (TCP calls these "segment" numbers)
- Sender or receiver fails, or line breaks:
  - After excessive retransmissions, or
  - After excessive wait for missing data, or
  - After not seeing "keepalives" for too long

  ... ***break the connection and report "end of file"***

Problems with this approach?

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- Channel can break because of a transient condition!
- Example: overloaded machine, connection that temporarily fails, router crashes and must reboot itself (all are relatively common conditions)
- Systems with many TCP channels: *some may break but others stay connected!*

Inconsistently broken TCP channels

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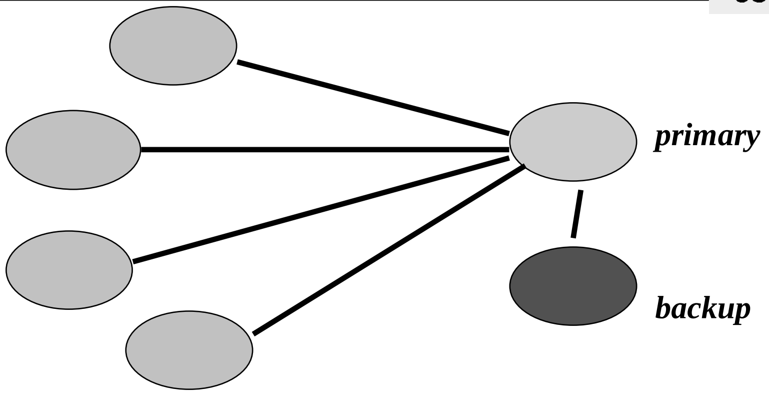

Clients initially connected to primary, which keeps backup up to date. (For example, in a database system)

Inconsistently broken TCP channels

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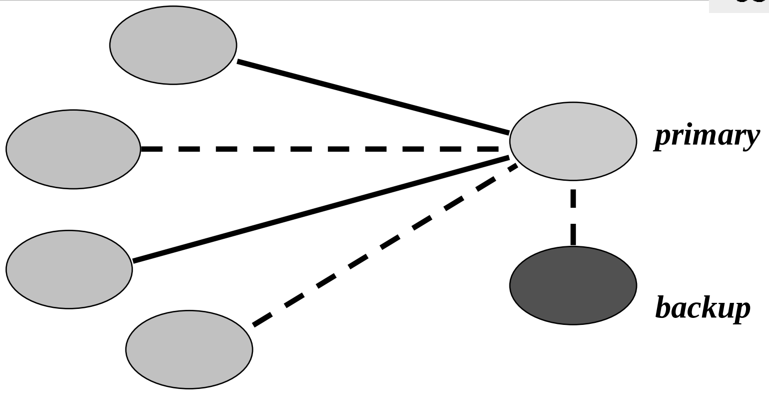

Transient problem causes some links to break but not all. Backup thinks it is now primary, primary thinks backup is down

Inconsistent outcome!

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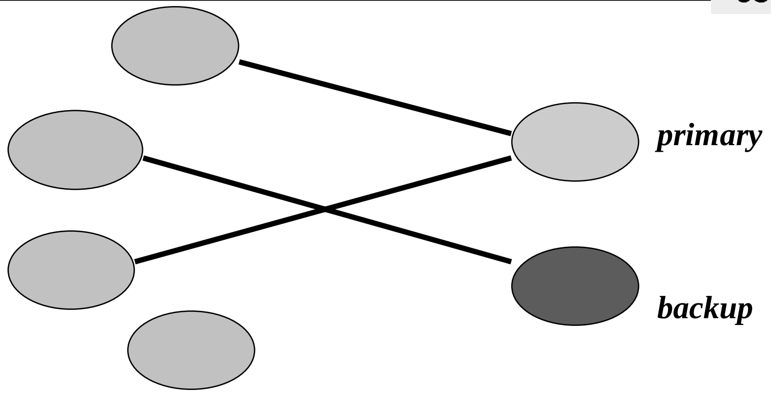

Some clients still connected to primary, but one has switched to backup and one is completely disconnected from both

A weird case seen in FTP

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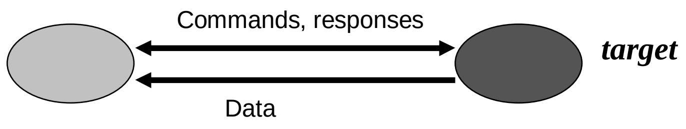

FTP (file transfer program) uses <u>two</u> TCP connections

A weird case seen in FTP

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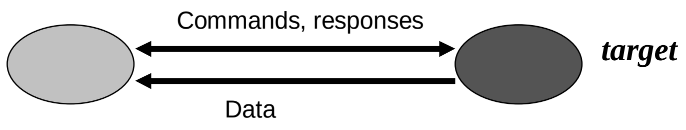

Suppose that for about 90 seconds, the target and end-user lose connectivity. One connection will break first!

Aside: Why don't they break at the exact same time?

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- Each TCP connection is sending data, keep-alives
- So why don't they both break at the identical instant in time when problems arise?

Aside: Why don't they break at the exact same time?

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- Answer: *They aren't synchronized.*
  - If one channel just got some data through and the other has been idle for a while, the first may have 90 seconds or so before it breaks but the second could be much closer to needing a keepalive ping. If that fails, it will disconnect while the first one stays connected

A weird case seen in FTP

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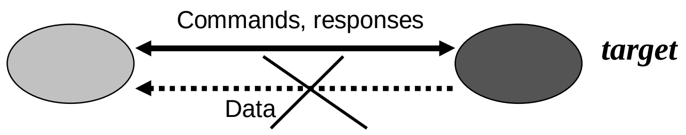

But if communication is now restored… the situation won't fix itself since the connection has already been lost

Why should this matter?

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- Suppose that primary and backup are a service used for air traffic control
  - Service tells controllers which parts of airspace are “available” for routing flights towards airport
  - Primary and backup may try and give *different* controllers access to the *same* airspace! Each thinks it is “in charge” for the system as a whole!
- This is our old split-brain problem but now TCP is causing it

Subtle semantics questions

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- Are the “reliability semantics” of TCP actually different from those of RPC?
  - In both cases, what you “know” is limited to what has been explicitly acknowledged
  - Both can report “failures” when none has occurred
  - Ultimately, TCP and RPC give same guarantees!
- Many systems run RPC over TCP as the “reliable” RPC option. Is this different from normal RPC?

And the answer

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- In a simple sense, they have the same properties
  - Both try to overcome failure
  - Both can mistakenly break a connection
- We think of TCP as the “reliable protocol” but in reality, it is just more reliable than UDP!

What might a better world look like?

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- Clearly, we need a notion of consistency
- What might be reasonable goals?

Possible consistency goals

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- Goal #1:
  - *Connections should only break if one of the endpoints actually fails*
  - *If the network itself is having problems, the application should be warned but the decision to break the connection should be one it takes explicitly*

Is this goal achievable?

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- At the core, becomes a question of how we detect failures
- Several cases
  - If the remote application crashes but the machine stays up, the remote machine can say “the app died”
  - If the machine crashed it just goes silent
  - If the network is hung, the machine *also* goes silent
- How can machine A learn that machine B has crashed?

Vogels: The world-wide failure detector concept

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- Werner Vogels asked
  - Suppose your neighbor stopped collecting his mail
  - Would you call the police and report that he was dead?
- More likely you might knock on the door and see if he is ok. Perhaps would phone him, or his daughter…

Vogels: The world-wide failure detector concept

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- Vogels points out that there are actually many ways to sense health in a modern network
  - We could ping the routers on the path and this would let us judge health of the network, to a degree
  - We could contact some related but different machine, like the email receiver (SMTP) contact for that machine
- He found a dozen or so of these…

Vogels' vision

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- He proposed that we build a new kind of Internet service
- It would
  - Get told when an application (or a machine) starts
  - Monitor its health
  - Tell interested parties if something fails

Killing a sick machine

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- Suppose an apparently sick machine recovers?
  - With Windows XP or Linux this is common
  - E.g. it was hung in a driver or printing error messages…
- If we already reported it dead, we might want to pull the plug and let it reboot! (Otherwise, we lied when we reported it dead, and Werner never lies…)

Consistency issue

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- TCP and RPC could be rewired to talk to this health monitoring service
- Now, if the service avoids bad scenarios, TCP and RPC would behave more sensibly
  - E.g. client would only see a broken connection if the primary is *really* dead, and in this case backup would also know and can take over
  - Slow connection (but no failure notification) could be reported to application…

Turtles all the way down

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- But how can we build our service?
  - Service itself can't be on just one machine or if that dies, it dies!
  - So we need to build a replicated service… how will it track health of its own members?

Membership service

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- Leads to a new core goal
  - We want to build a “membership service”
  - It runs in the Internet
  - It has multiple members of its own
  - Applications can register with it
    - I’m “outlook contacts database” on “fafnir.cs.cornell.edu” and I’m alive!
    - Please monitor “oracle” for me on “…”
- And it does all the work of tracking its own health, monitoring them, reporting events

Consistency goals?

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- Q: What is the simplest way to formalize exactly what consistency goals we seek for our membership service?

Consistency goals?

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- Q: What is the simplest way to formalize exactly what consistency goals we seek for our membership service?
- A: It should act like a single server program on a single machine… but one that never fails or becomes unavailable

Implementing our server?

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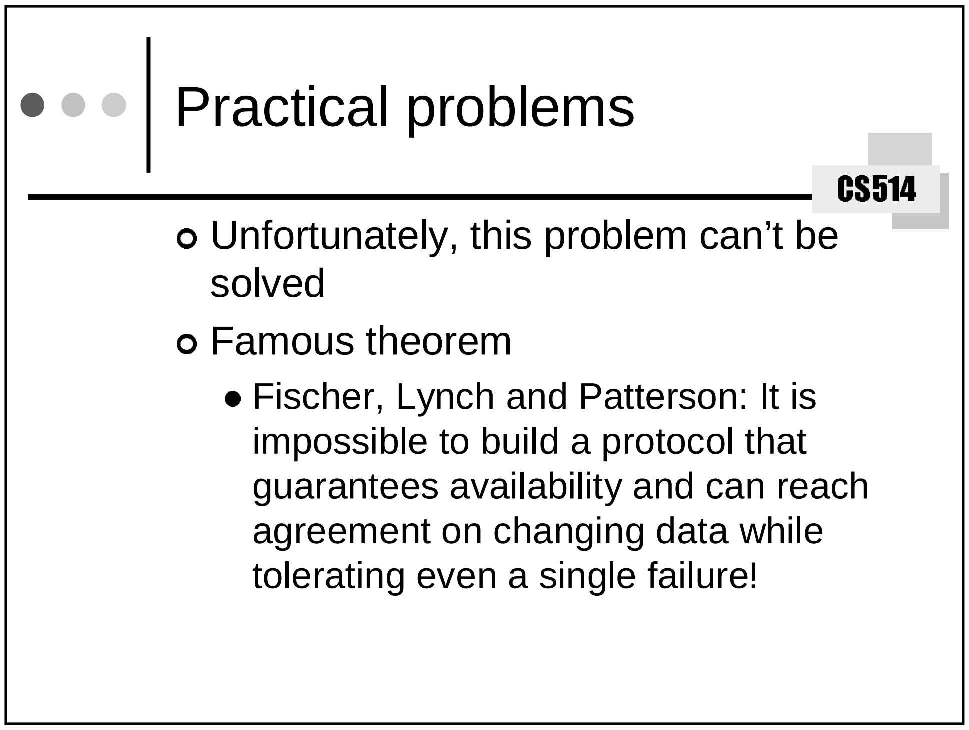
- In the “real world” it needs to have
  - Representatives at lots of places
    - Like the DNS
  - They somehow cooperate to pretend to be just a single program at a single place
  - And they use available monitoring interfaces to watch things
- Then would modify TCP, RPC to use it
  - Not a trivial thing since IETF would probably throw a conniption fit! (Not end-to-end…)



Practical problems

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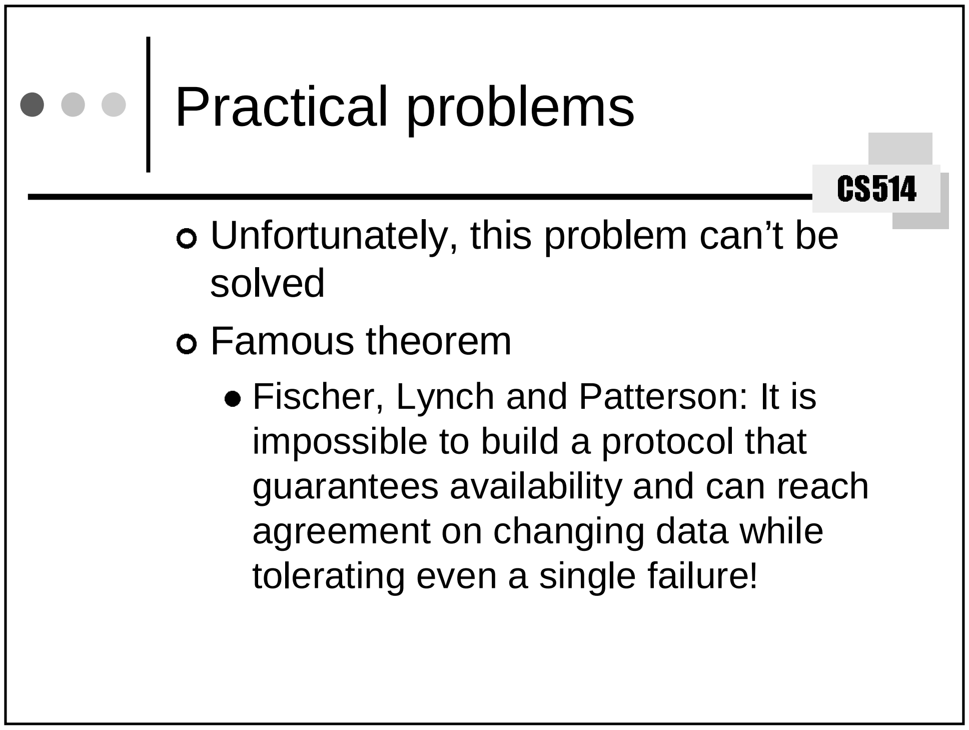
- Unfortunately, this problem can’t be solved
- Famous theorem
  - Fischer, Lynch and Patterson: It is impossible to build a protocol that guarantees availability and can reach agreement on changing data while tolerating even a single failure!



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So who cares?

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- This particular theorem limits what we can hope to achieve
- But there *is* a way to work around it
  - Basically, we won't guarantee availability
  - Our service will only promise to try to maintain availability
  - Alas it may make mistakes… but
    - If the service says "He's dead, Jim"
    - It simultaneously pulls a phaser from its pocket and fires!
    - "But Bones, he was alive!" "No, he's dead now"

Simplified problem

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- We want to build a service that tracks its own membership
  - It tries to remain available during failures (but sometimes could hang if the failure sequence is awful enough)
  - It uses pings or other tools to monitor its own members
  - And it needs to avoid somehow partitioning into two services if the network itself splits (partitions), forming two disconnected subnets!

We'll return to this in 1 week

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- After the break, we'll
  - Design a solution to this problem
  - Think about how it could solve the TCP and RPC consistency problem
  - Use it to build various forms of reliable multicast

…. And we'll see how such a service was used to replicate the state of the Swiss Stock Exchange!