

# CLOUD COMPUTING CONCEPTS

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TIME AND ORDERING

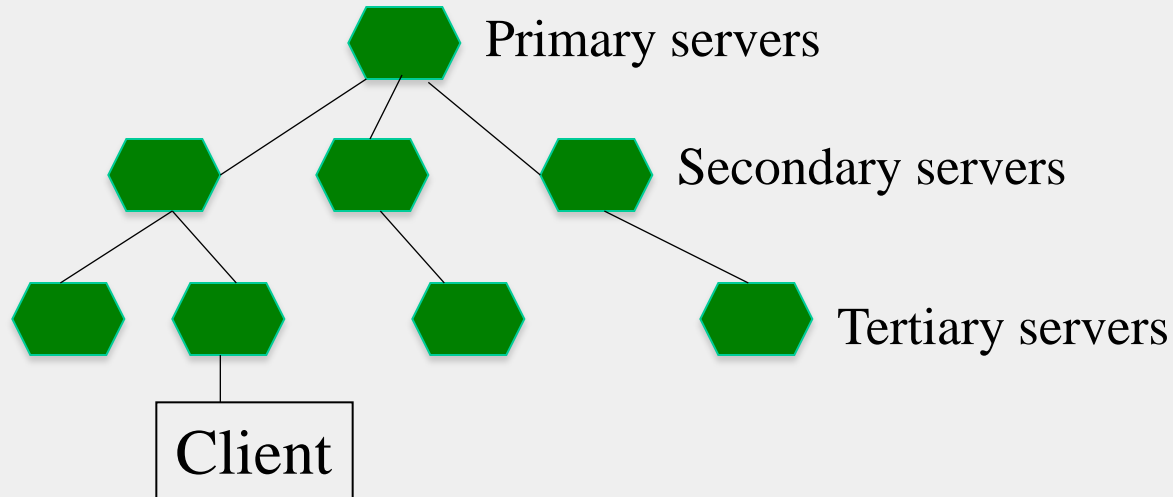
Lecture C

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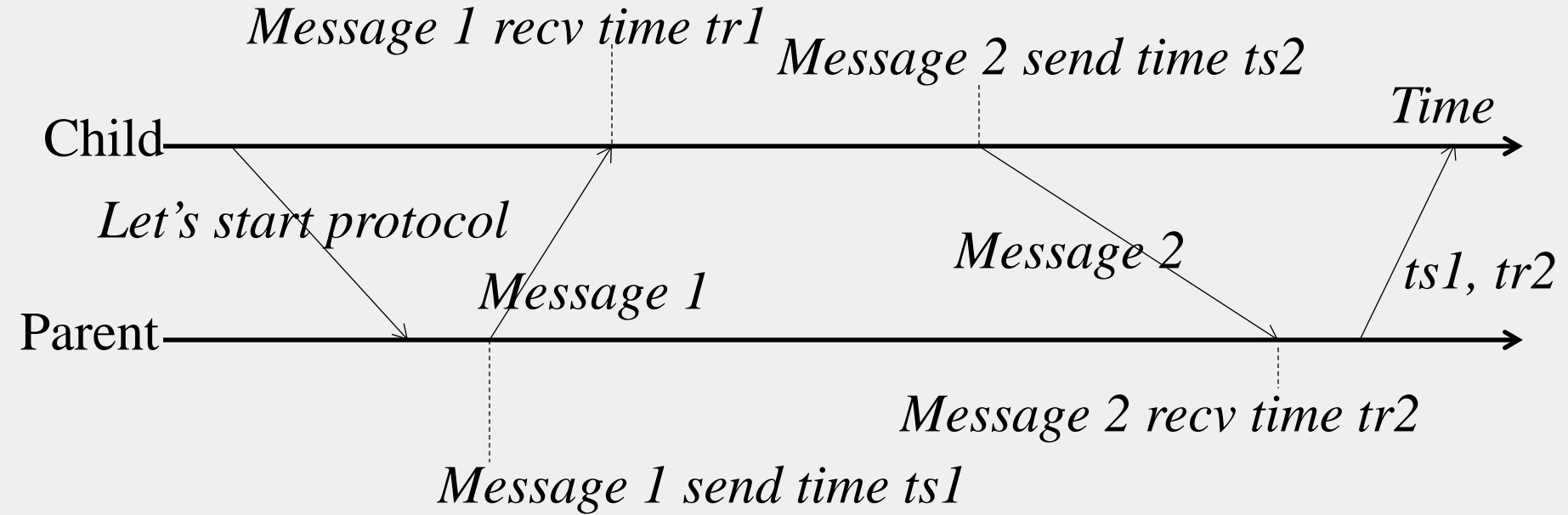
NTP

# NTP = NETWORK TIME PROTOCOL

- NTP servers organized in a tree
- Each client = a leaf of tree
- Each node synchronizes with its tree parent



# NTP Protocol



# WHAT THE CHILD DOES

- Child calculates *offset* between its clock and parent's clock
- Uses *ts1*, *tr1*, *ts2*, *tr2*
- Offset is calculated as

$$o = (tr1 - tr2 + ts2 - ts1)/2$$

# WHY $o = (tr1 - tr2 + ts2 - ts1)/2$ ?

- Offset  $o = (tr1 - tr2 + ts2 - ts1)/2$
- Let's calculate the error
- Suppose real offset is *oreal*
  - Child is ahead of parent by *oreal*
  - Parent is ahead of child by *-oreal*
- Suppose one-way latency of Message 1 is  $L1$  ( $L2$  for Message 2)
- No one knows  $L1$  or  $L2$ !
- Then

$$tr1 = ts1 + L1 + o_{real}$$

$$tr2 = ts2 + L2 - o_{real}$$

# WHY $o = (tr1 - tr2 + ts2 - ts1)/2$ ?

- **Then**

$$tr1 = ts1 + L1 + o_{real}$$

$$tr2 = ts2 + L2 - o_{real}$$

- **Subtracting second equation from the first**

$$o_{real} = (tr1 - tr2 + ts2 - ts1)/2 + (L2 - L1)/2$$

$$\Rightarrow o_{real} = o + (L2 - L1)/2$$

$$\Rightarrow |o_{real} - o| < |(L2 - L1)/2| < |(L2 + L1)/2|$$

– Thus, the error is bounded by the round-trip-time

# AND YET...

- **We still have a non-zero error!**
- **We just can't seem to get rid of error**
  - Can't, as long as message latencies are non-zero
- **Can we avoid synchronizing clocks altogether and still be able to order events?**