Rapid Clock Synchronisation for Ubiquitous Sensing Services Involving Multiple Smartphones

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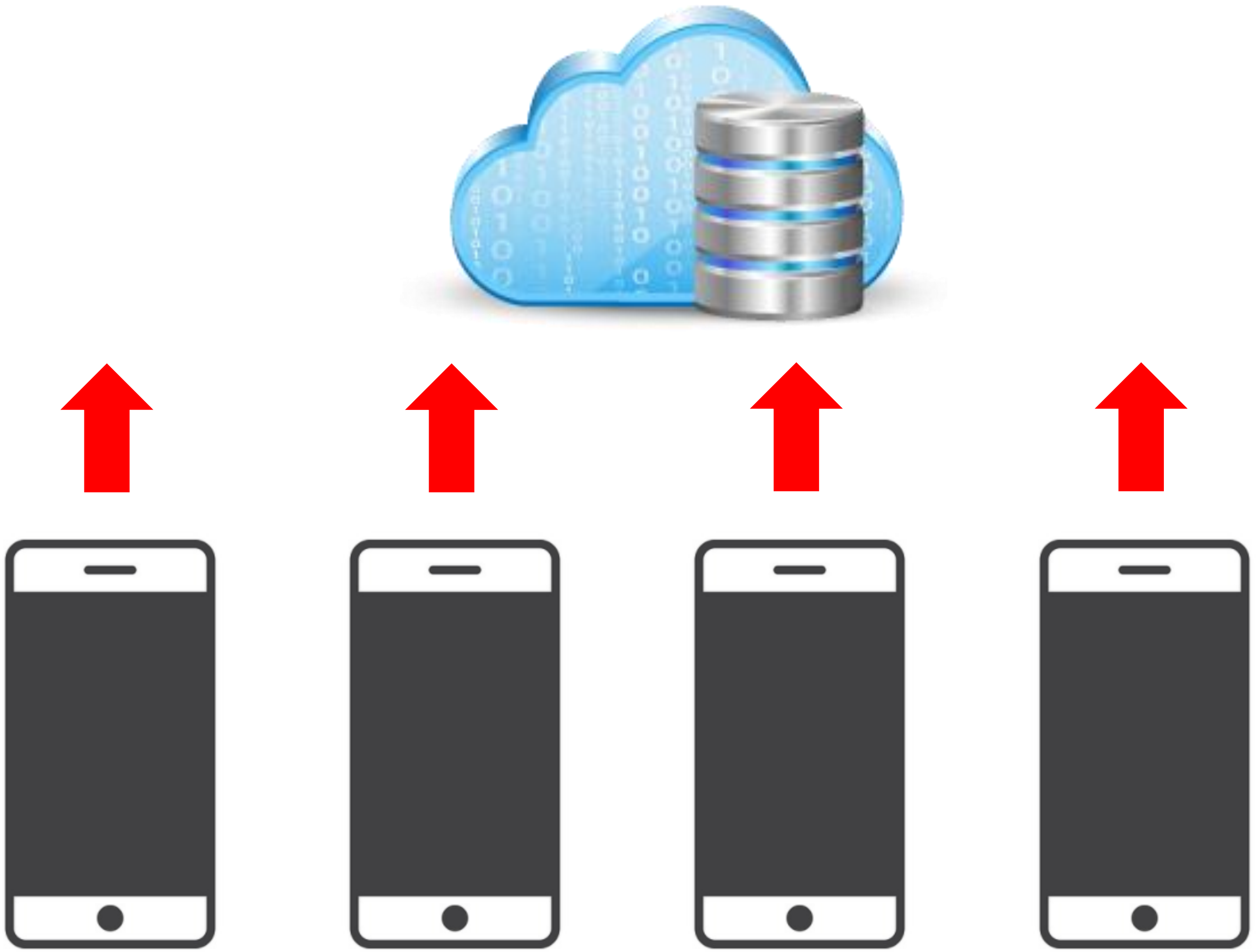
Smartphone Sensors and Apps

http://funf.org/about.html

Sensing with Multiple Phones



Phone Clock Has Drift

Challenge:

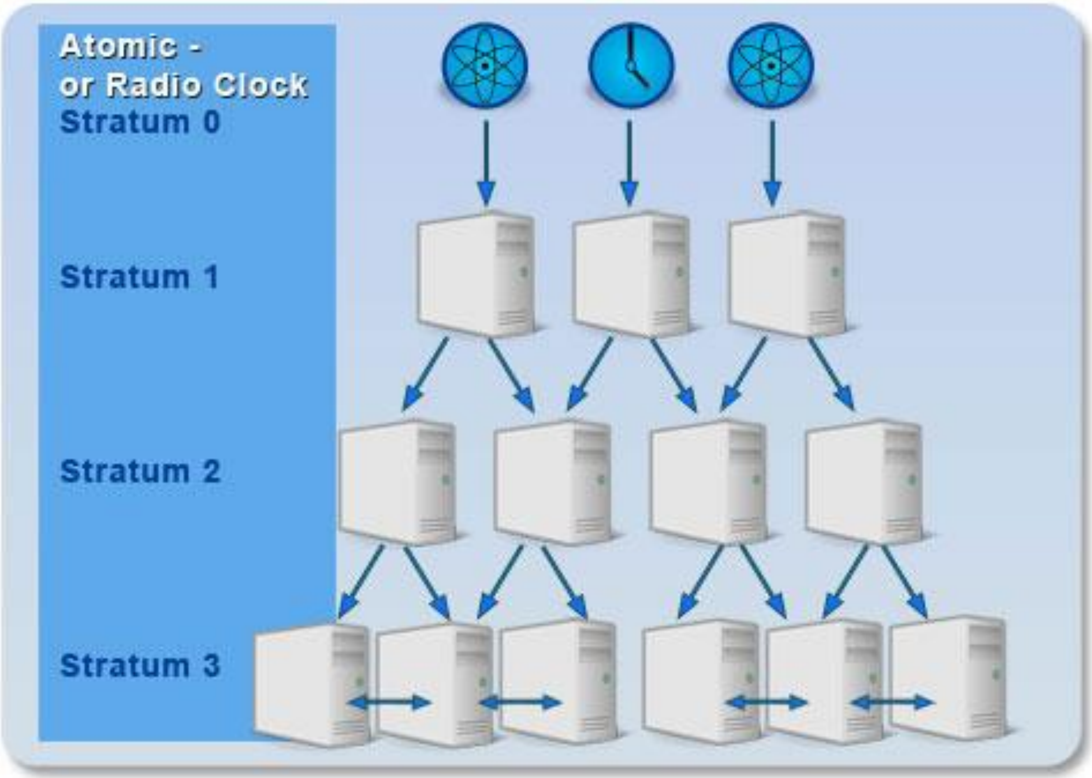
To synchronise clock on phones

Related Work

Clock Synchronisation:

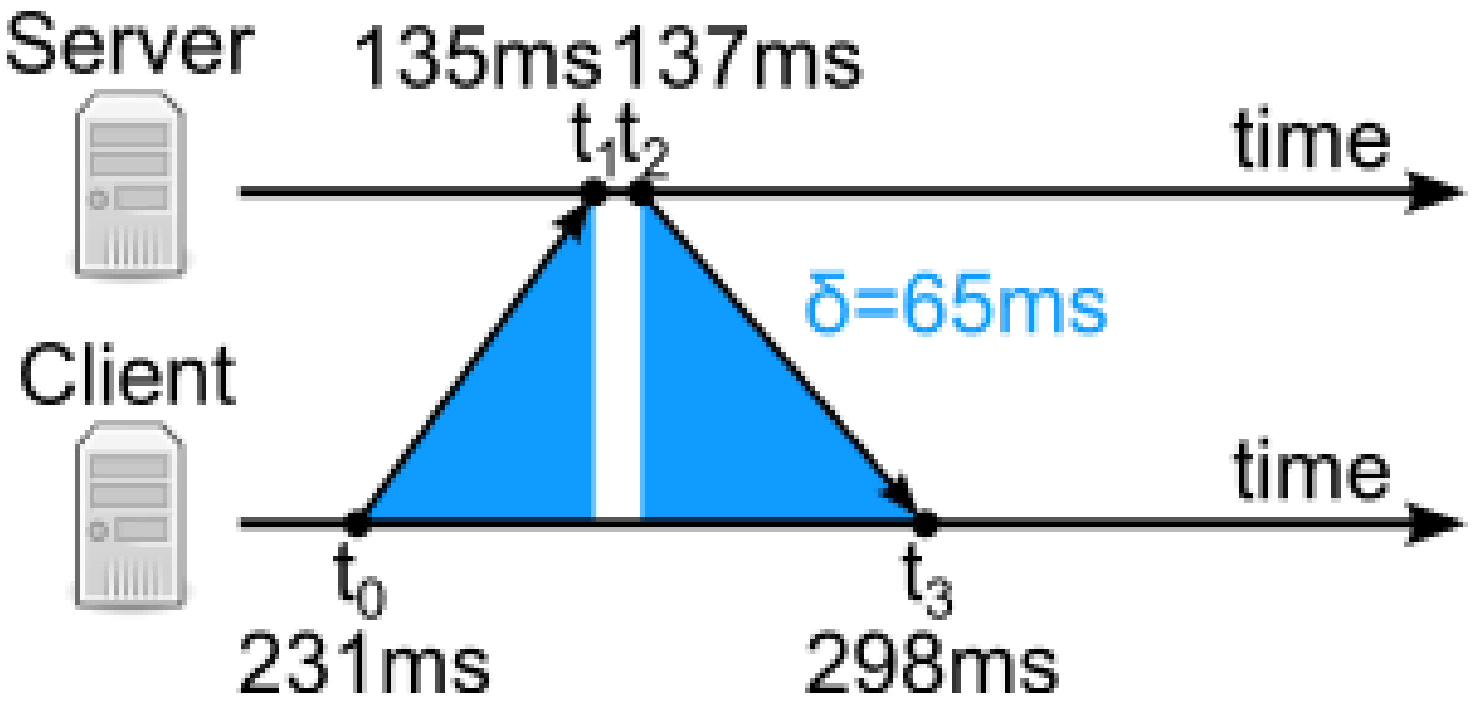
1. Network Time Protocol (NTP)
2. Precision Time Protocol (PTP)
3. GPS Clock Synchronisation

Network Time Protocol (NTP)

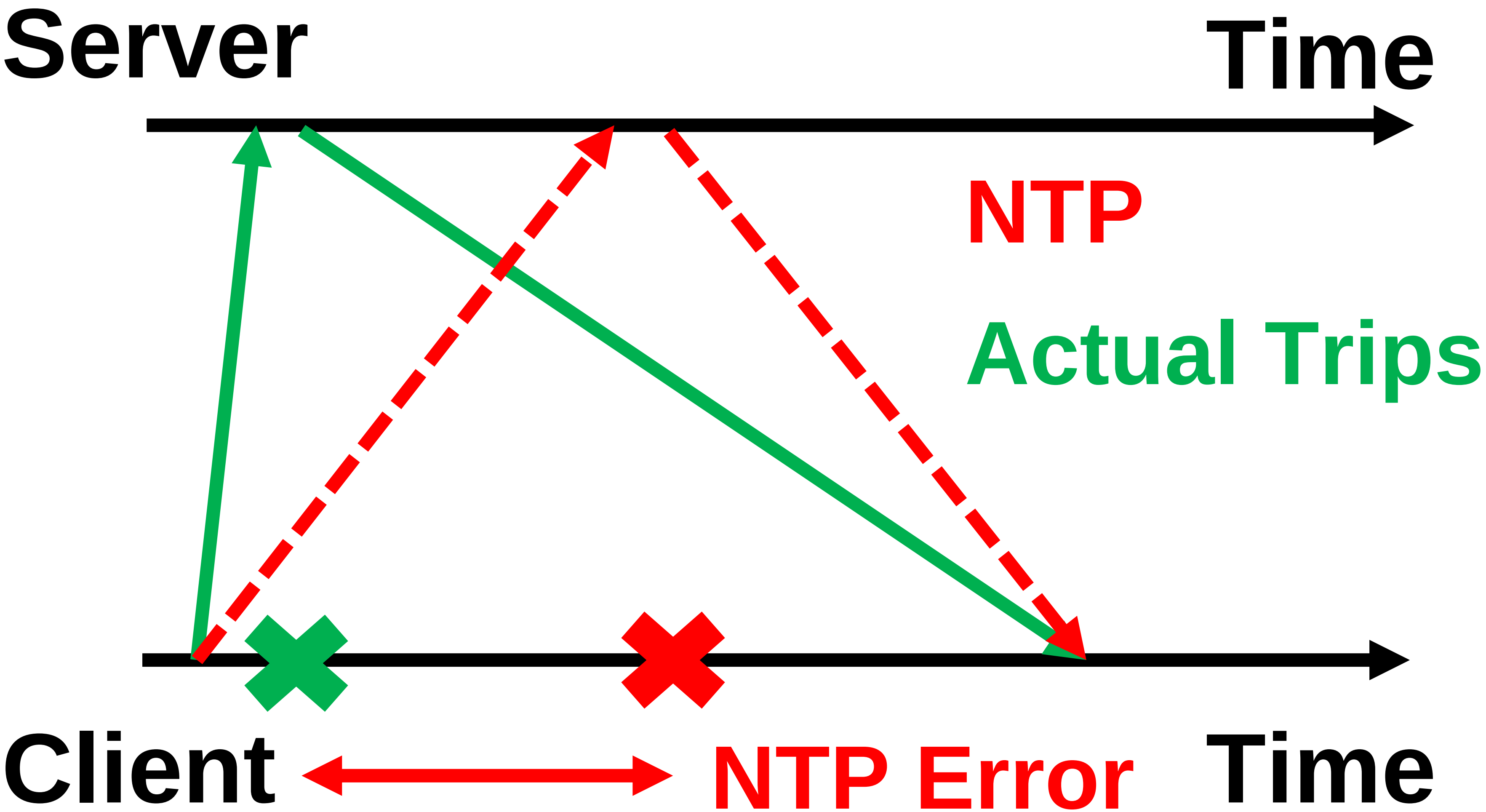


A stratum model

Network Time Protocol (NTP)



NTP can be inaccurate:



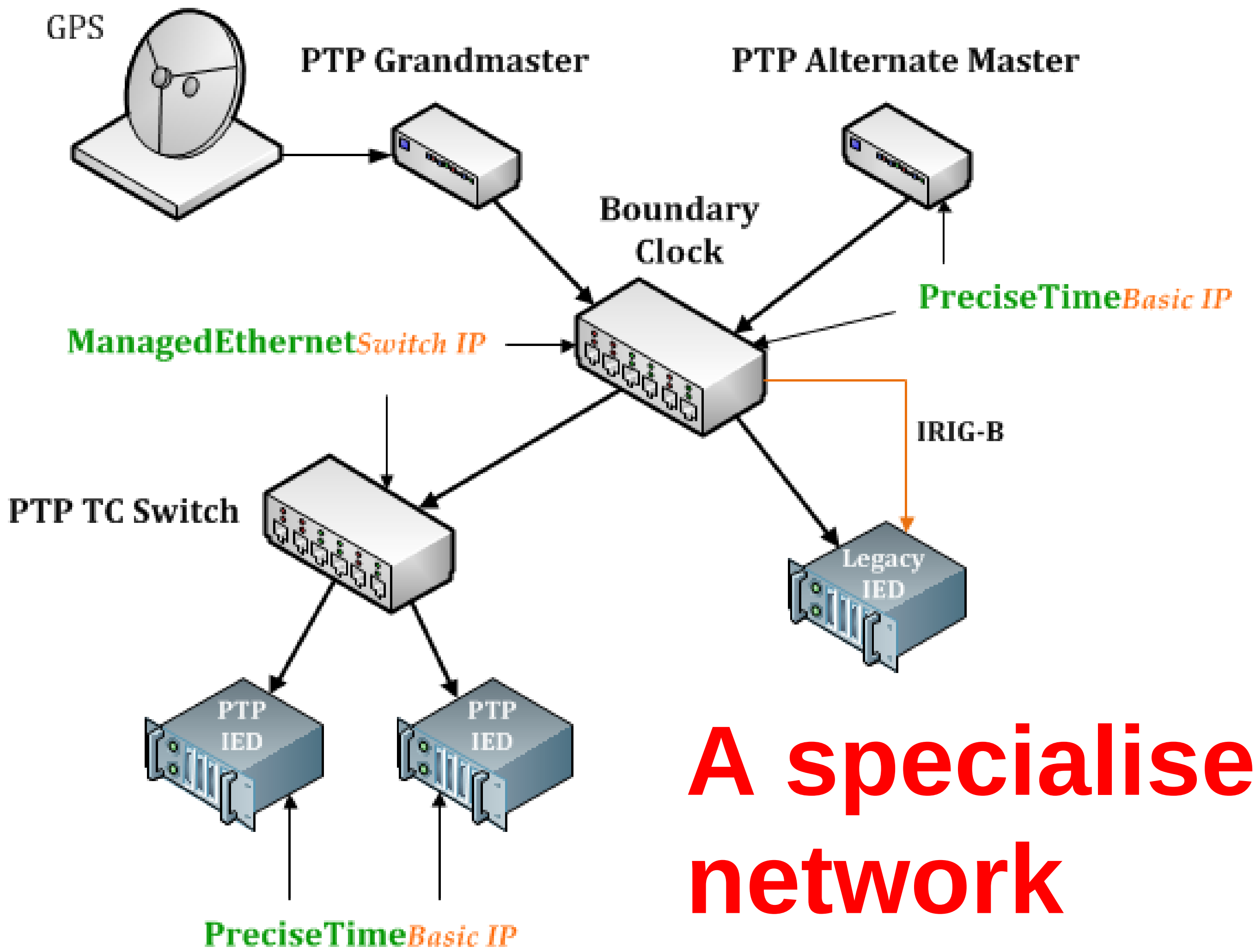
To make use of NTP

Collect many samples, do:

1. Linear Programming; or
2. Linear Regression(fitting)

Error can be minimised:10-100 ms

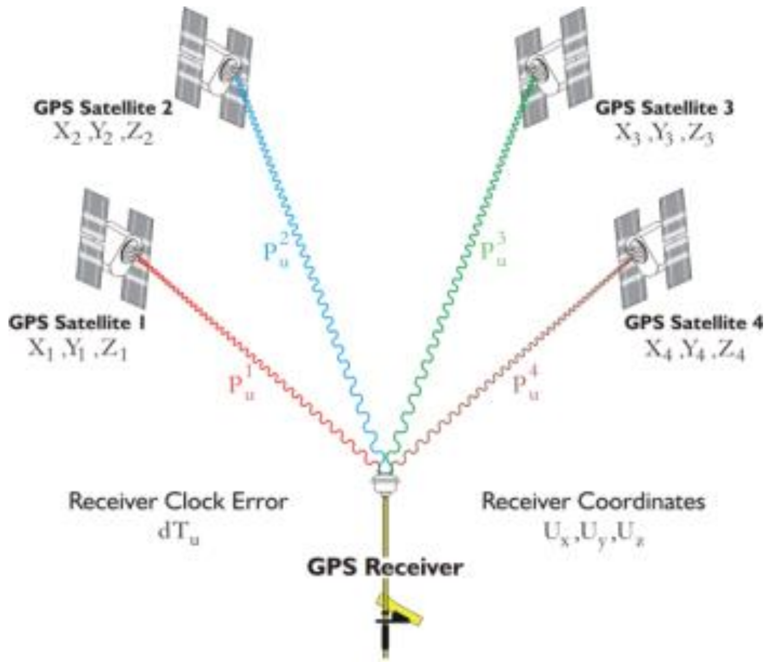
Precision Time Protocol (PTP)



A specialised network

http://www.meinberg.in/support/information/ntp-the-network-time-protocol.htm

GPS



$$\rho_u^1 = \sqrt{(X_1 - U_x)^2 + (Y_1 - U_y)^2 + (Z_1 - U_z)^2} + c(dT_u)$$

$$\rho_u^2 = \sqrt{(X_2 - U_x)^2 + (Y_2 - U_y)^2 + (Z_2 - U_z)^2} + c(dT_u)$$

$$\rho_u^3 = \sqrt{(X_3 - U_x)^2 + (Y_3 - U_y)^2 + (Z_3 - U_z)^2} + c(dT_u)$$

$$\rho_u^4 = \sqrt{(X_4 - U_x)^2 + (Y_4 - U_y)^2 + (Z_4 - U_z)^2} + c(dT_u)$$

http://geospatialrevolution.psu.edu/educators/trilateration.html

NTP as the base for ubi-sensing

Reasons:

1. Available anywhere on Internet
2. PTP needs LAN infrastructure
3. GPS is restricted by signals, power-hungry and hurts location privacy.

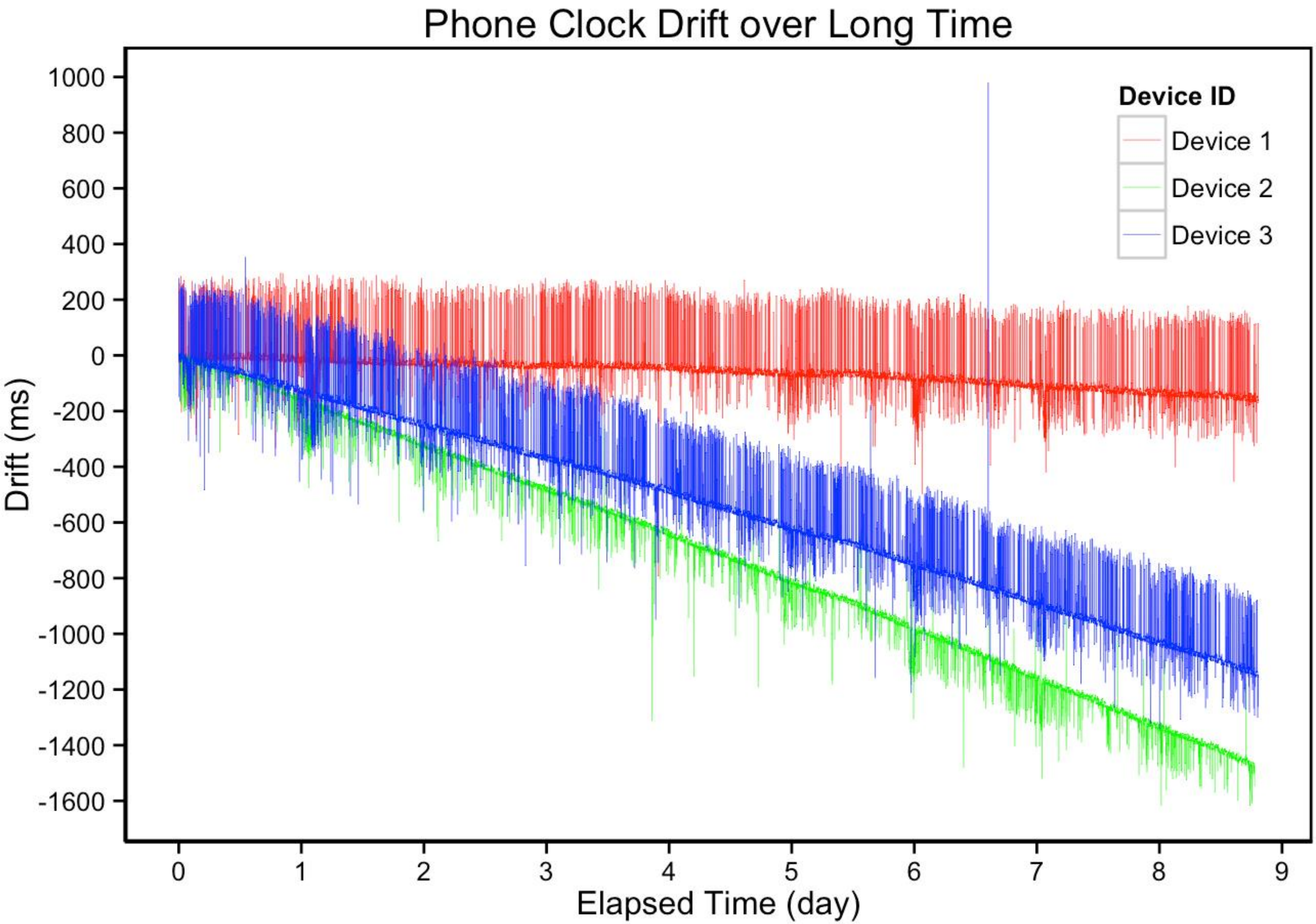
Phone Clock Drift

How large can this drift be?

Study 1

Running for 9 days:

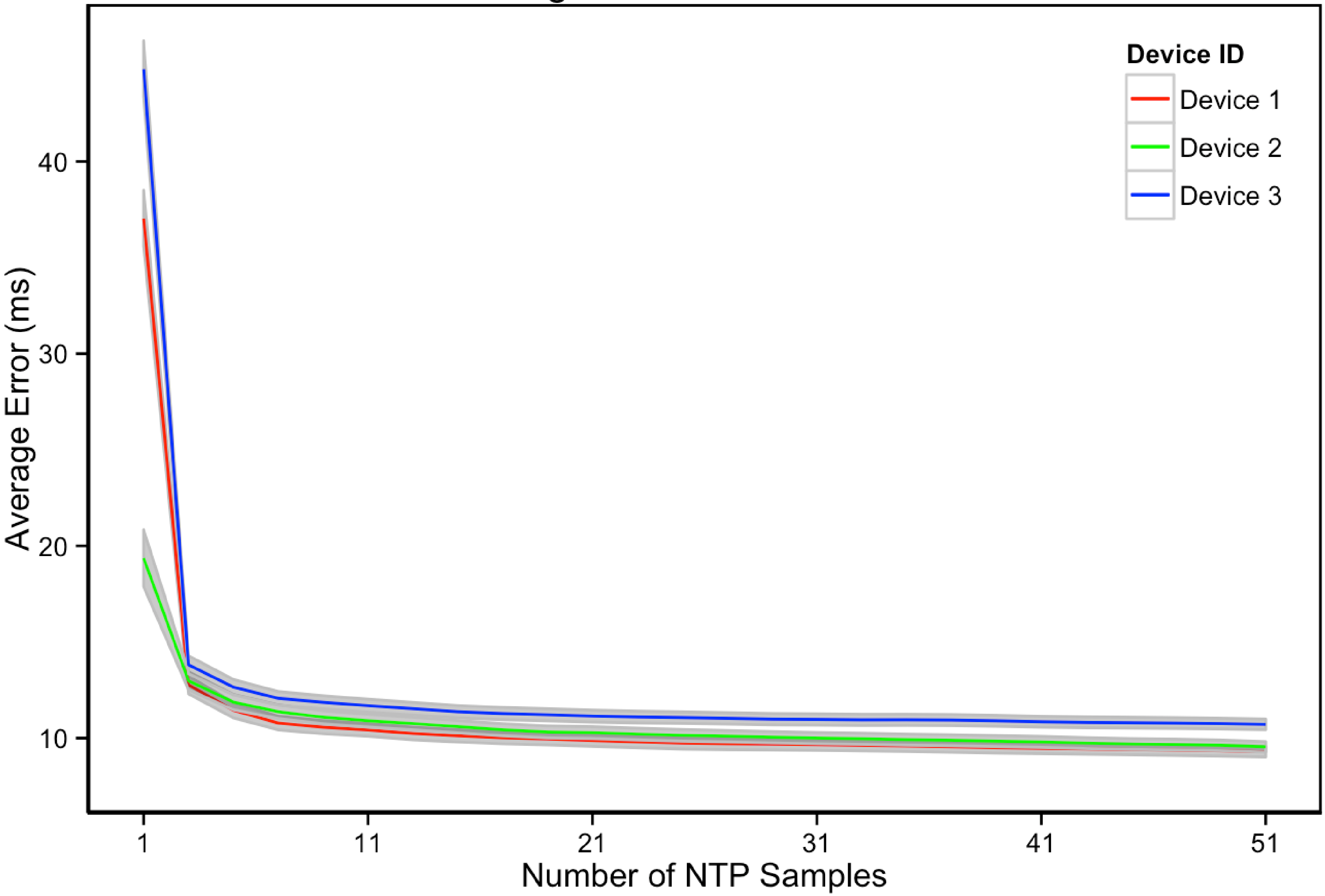
1. 3 identical phones
2. Connected to WiFi
3. Collecting NTP sample per minute

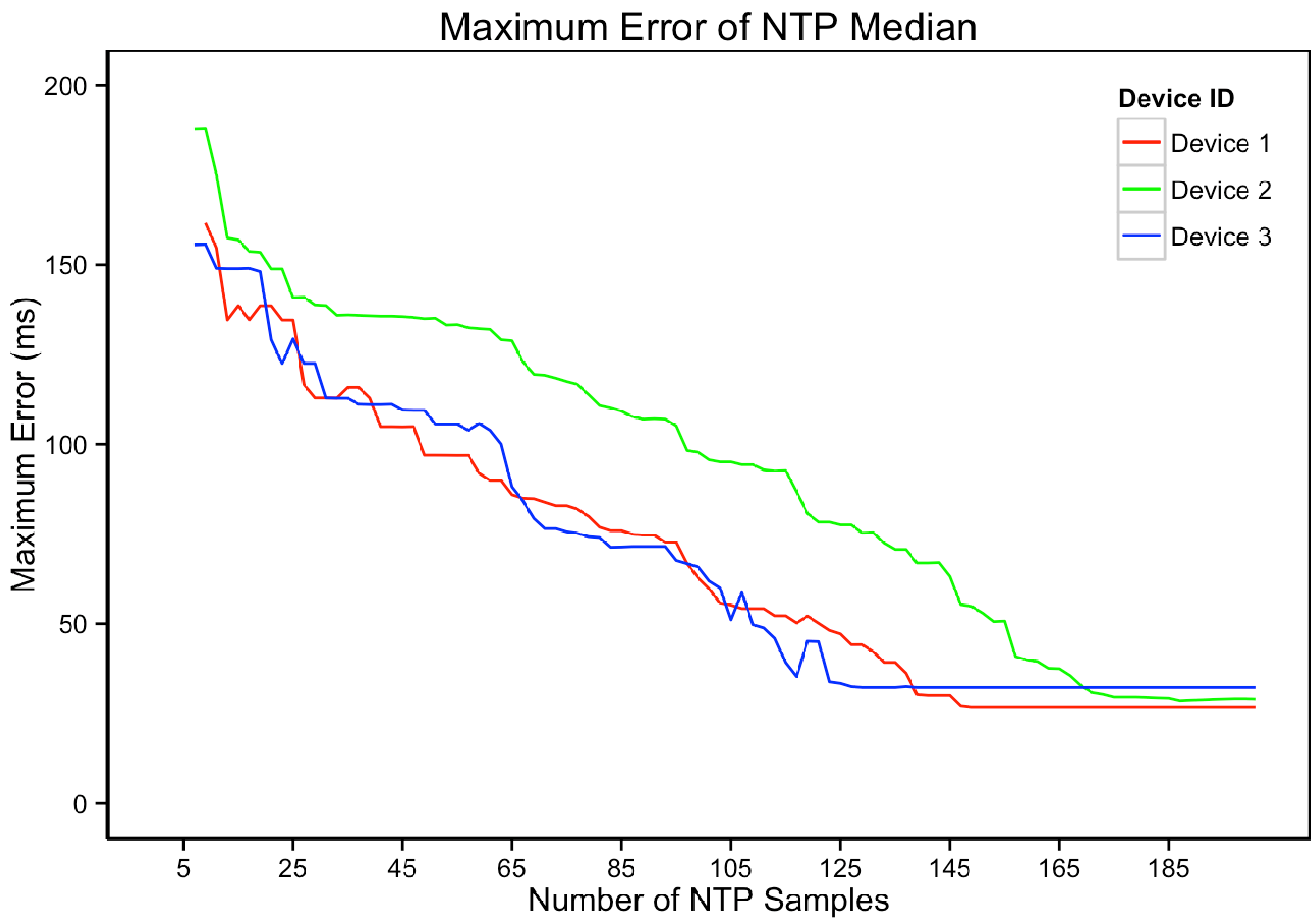

Phone Clock Drift over Long Time
Device ID
Device 1
Device 2
Device 3
1000
800
600
400
200
0
-200
-400
-600
-800
-1000
-1200
-1400
-1600
Drift (ms)
0
1
2
3
4
5
6
7
8
9
Elapsed Time (day)

Rapid Clock Synchronisation

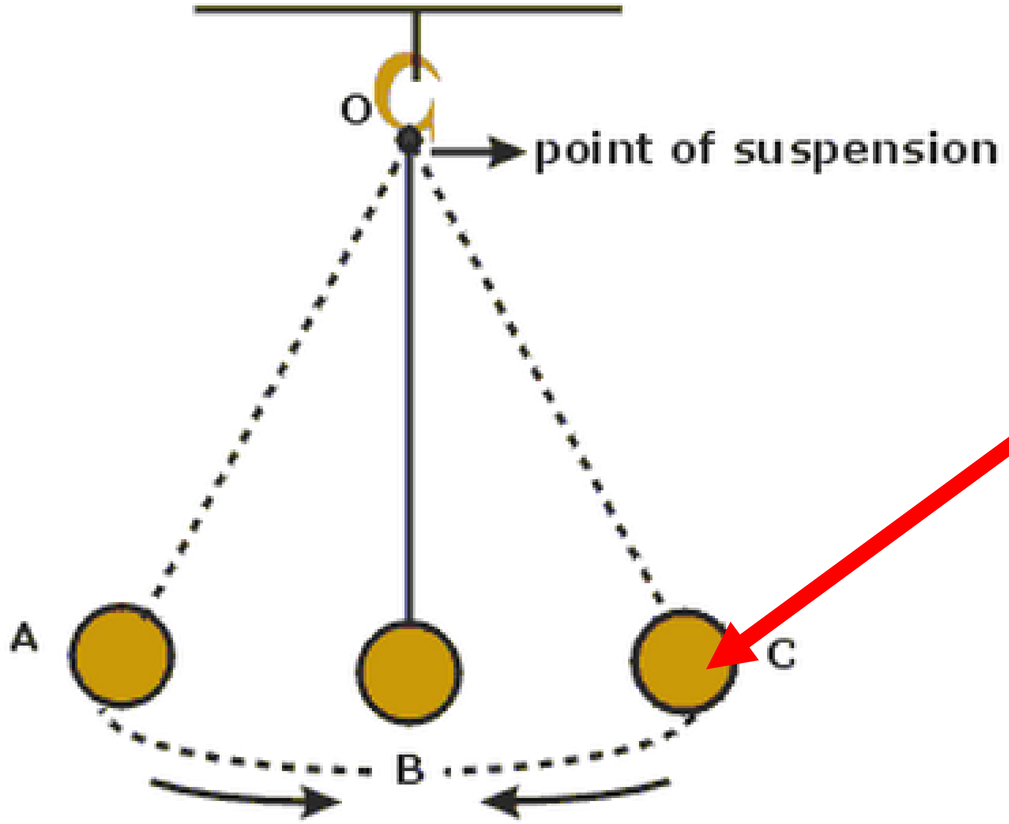
Using the median of several NTP Samples

Average Error of NTP Median

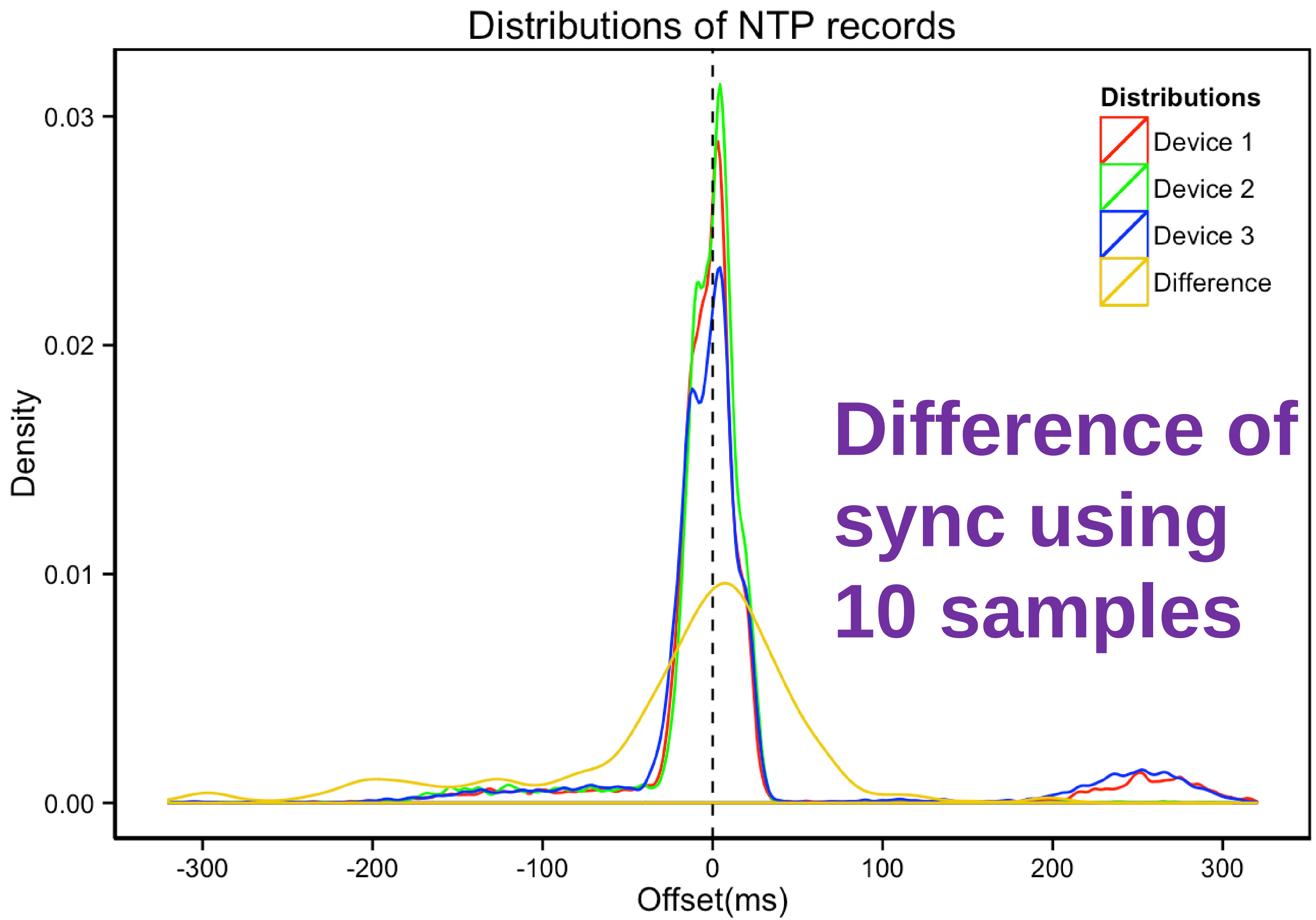



Maximum Error of NTP Median
Device ID
Device 1
Device 2
Device 3
Maximum Error (ms)
0
50
100
150
200
5
25
45
65
85
105
125
145
165
185
Number of NTP Samples

Study 2: measure pair-wise synchronisation difference



http://leacellodp.weebly.com/roller-coaster-project.html



Difference of sync using 10 samples

Take-away Points

1. Clock drift may be 150ms per day
2. NTP is most available and flexible
3. Using NTP median is a rapid way:
   a) Mean accuracy 12ms, 10 samples
   b) Worse case, <100ms, 97 samples

      <40ms, 157 samples

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