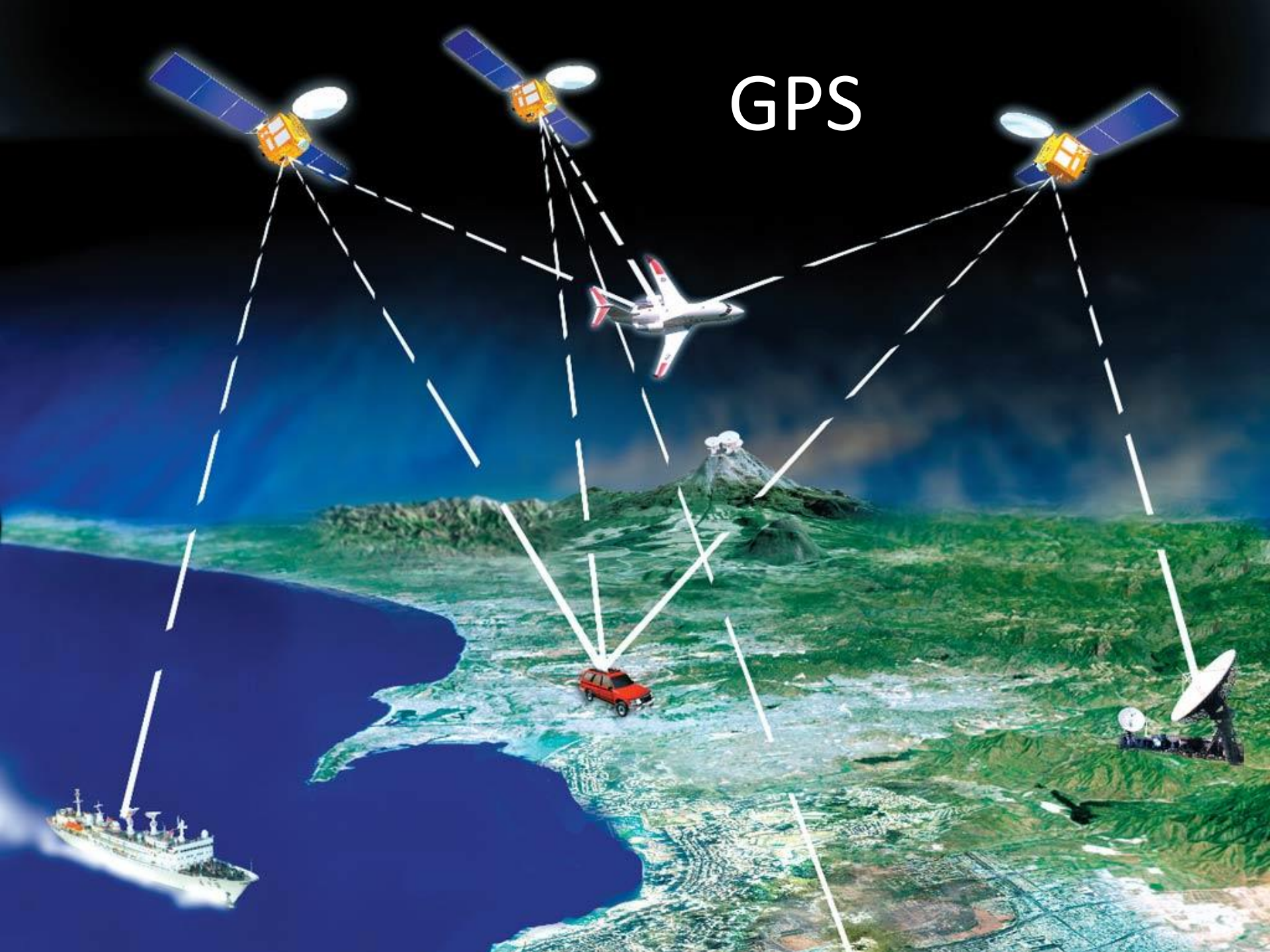


*Time is Money!*

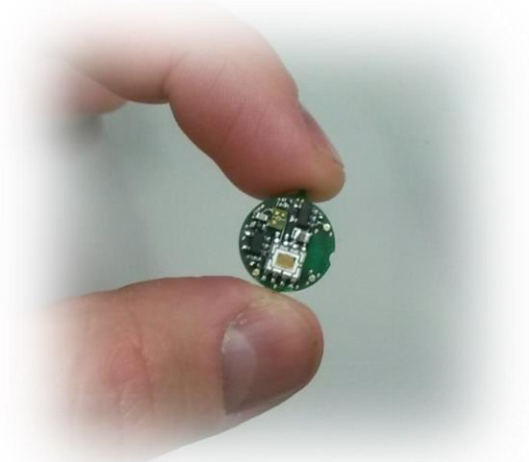


*Roger Wattenhofer*

# GPS



# UV Radiation



# Wireless Multi-hop Networks

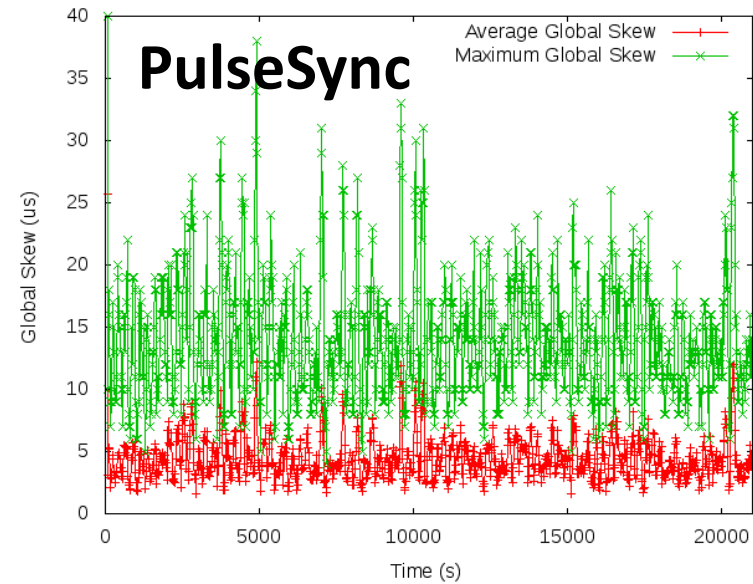
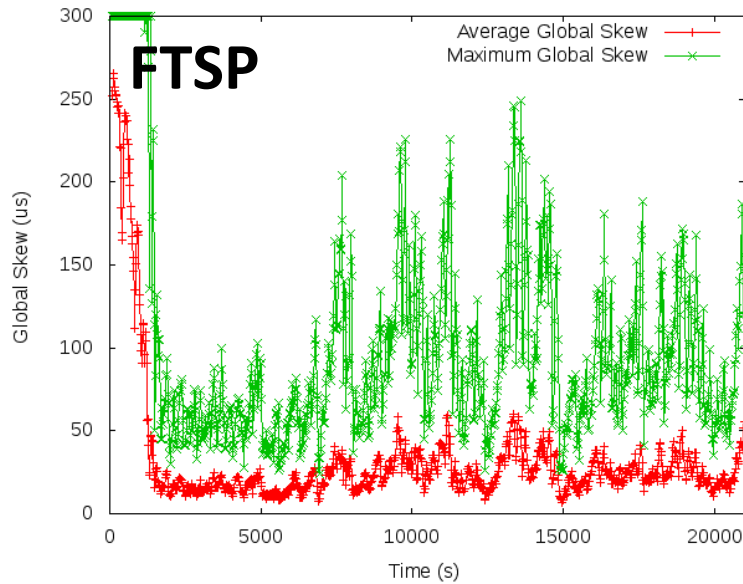


# Synchronization in Networks

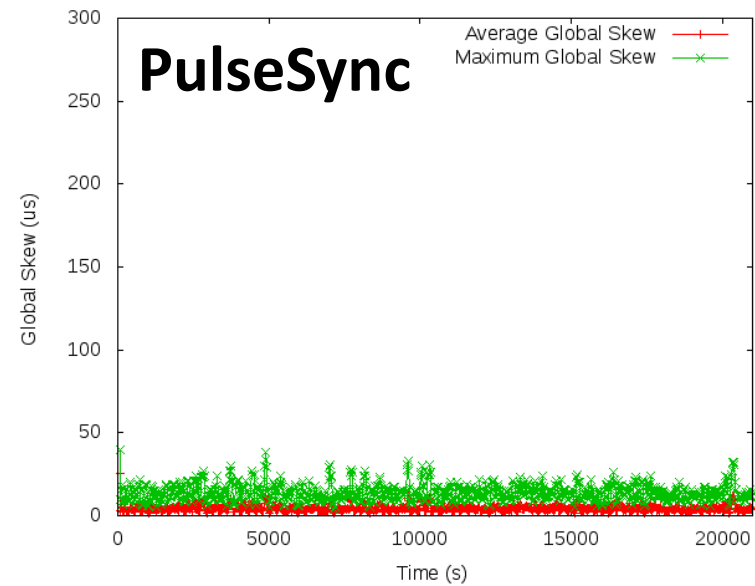
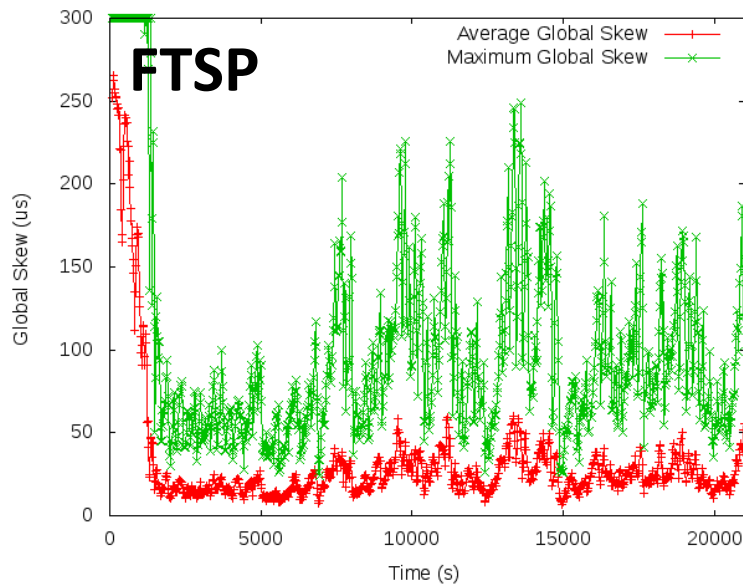


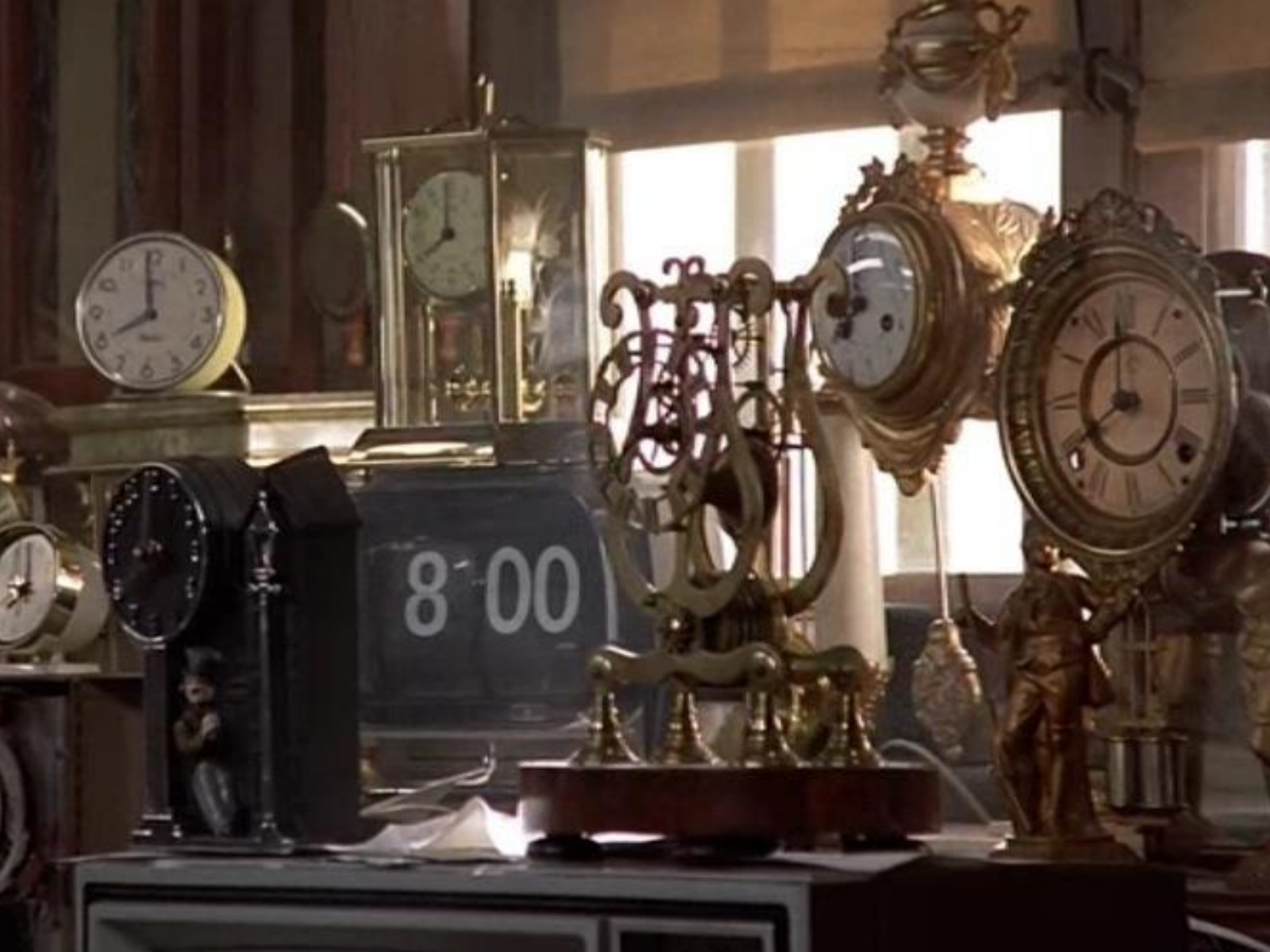
Theorem: Impossible to  
synchronize well,  
not even neighbors!

# Network Synchronization in Practice



# Network Synchronization in Practice





8:00





Synchronize  
Heart Rate  
with Music

Physical Logical





You probably used  
logical synchronization

Money



Bitcoin

# Bank of Bitcoin



# Spending Money



**Source**  
DONALD E. KNUTH  
COMPUTER SCIENCE DEPARTMENT  
STANFORD UNIVERSITY  
STANFORD, CA 94305-9045

11-3167/1210  
01

428

Date: 10 Aug 98

Pay to the Order of: Gabriel Valtente **Destination**

\$ 20.56 **Amount**

Two and 56/100 Dollars

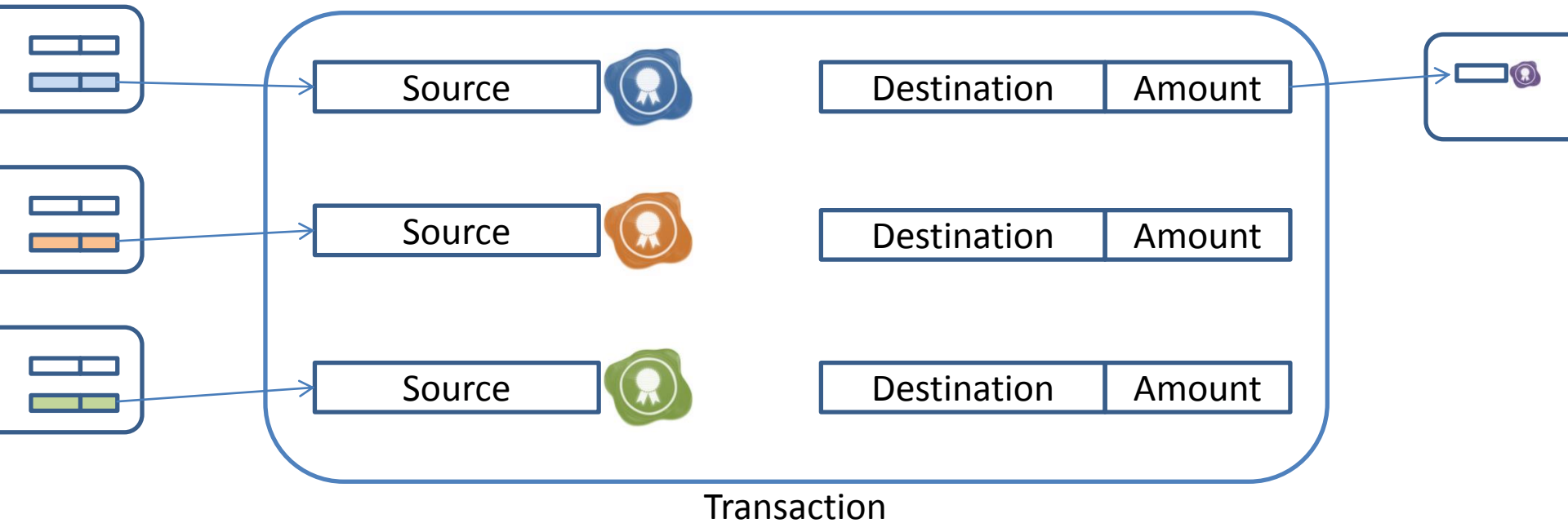
**America California Bank**  
2390 El Camino Real, Palo Alto, California 94306

For: 1450

**Signature**  
Donald Knuth

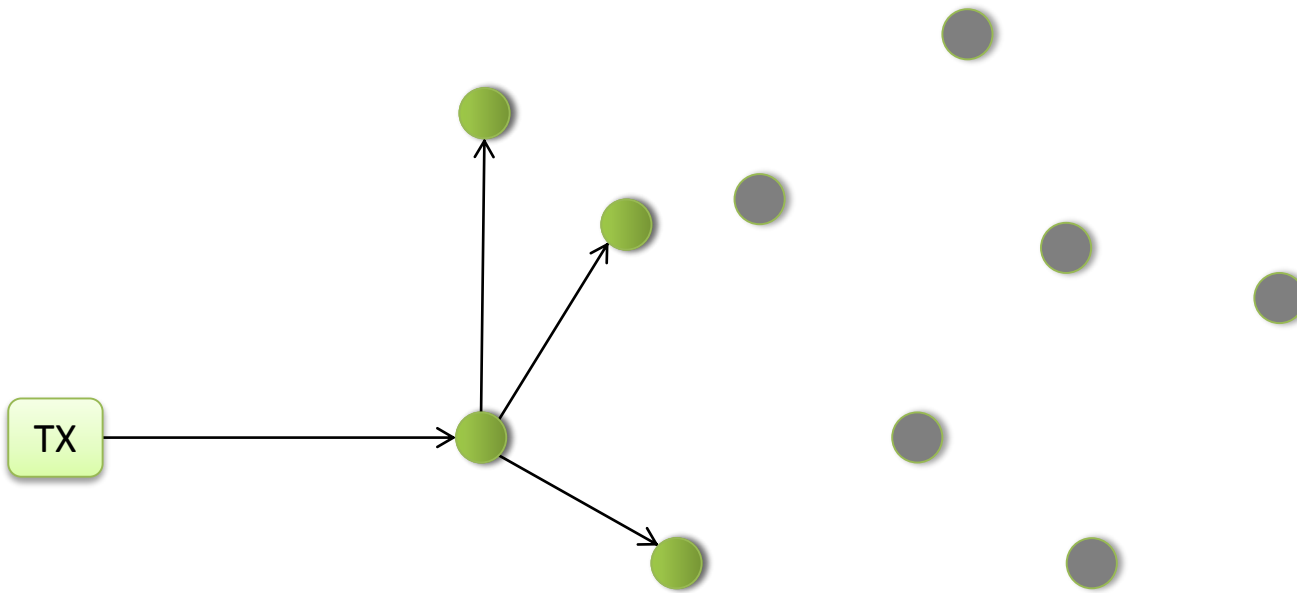
1: 1210316731:0428 011558490611

# Moving Money

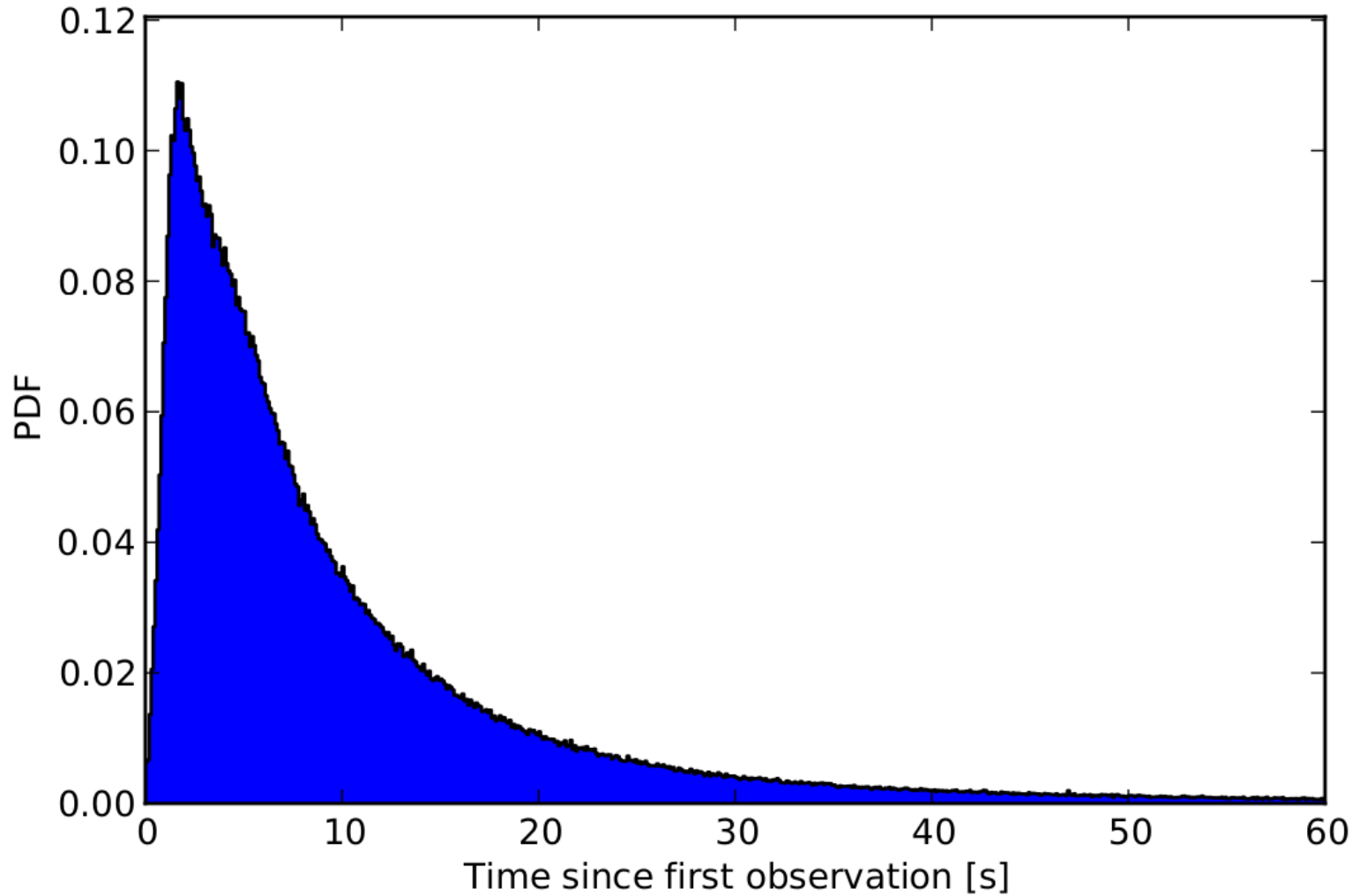




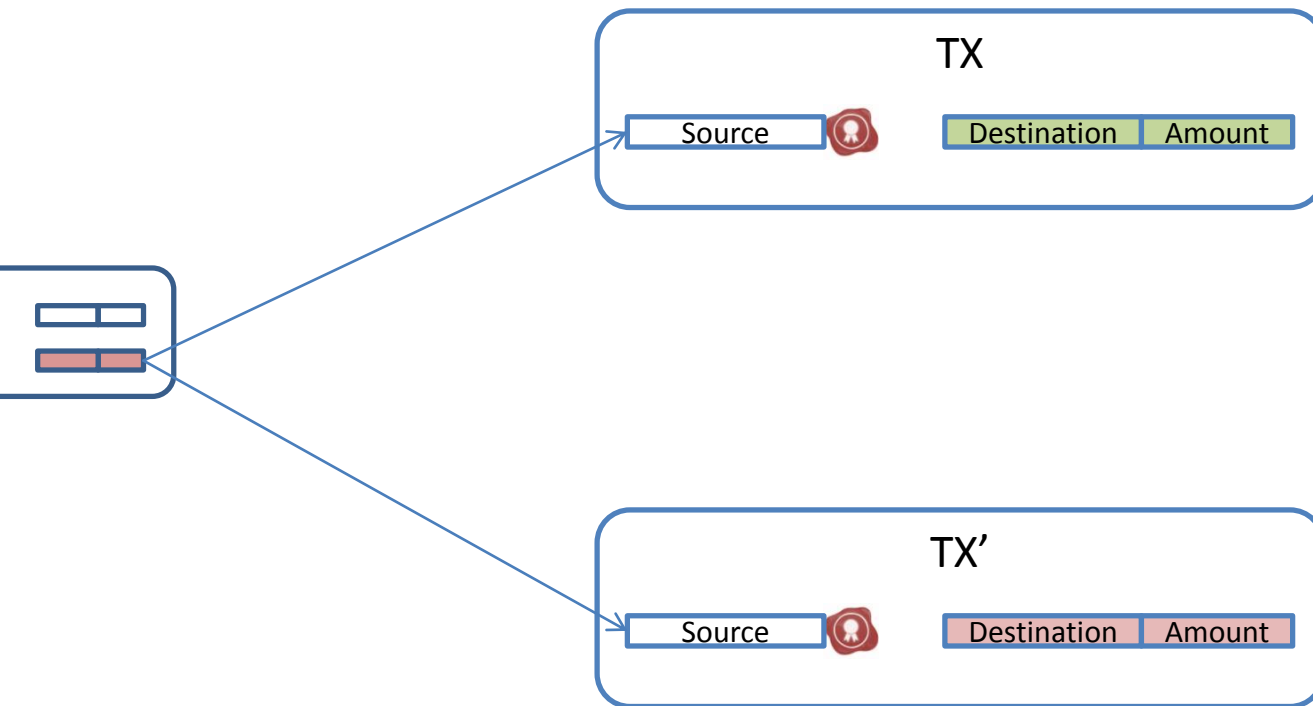
# Distributing the Bank



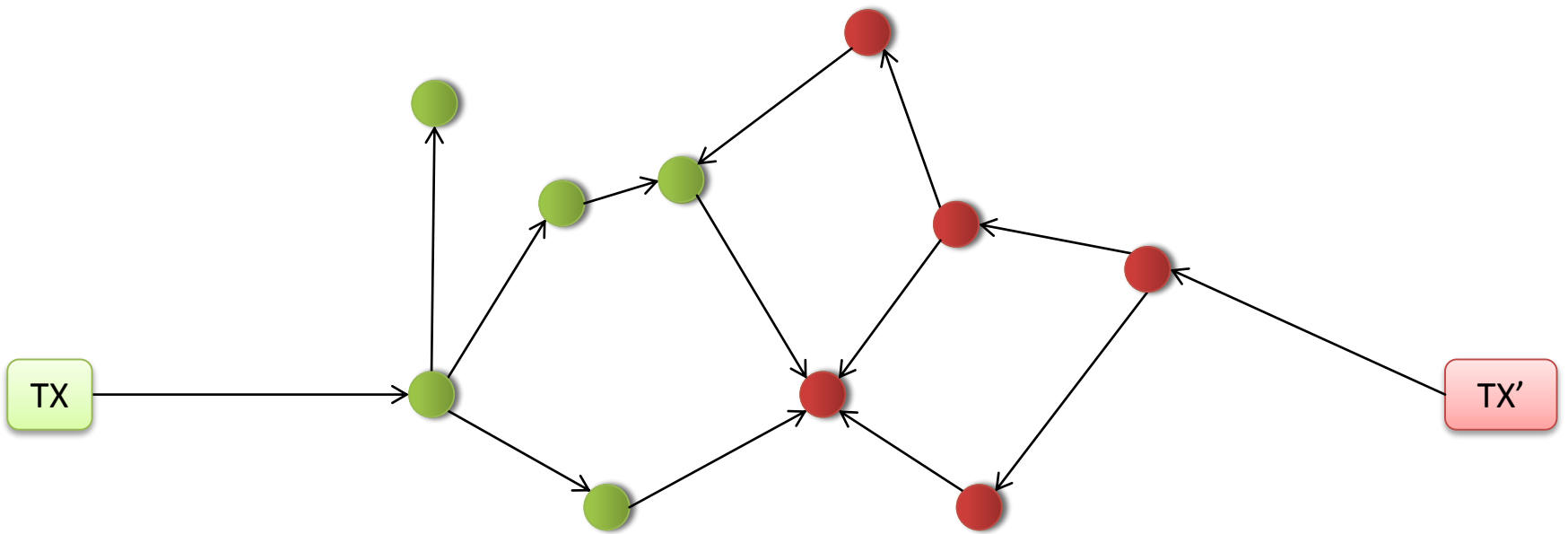
# Propagation Time



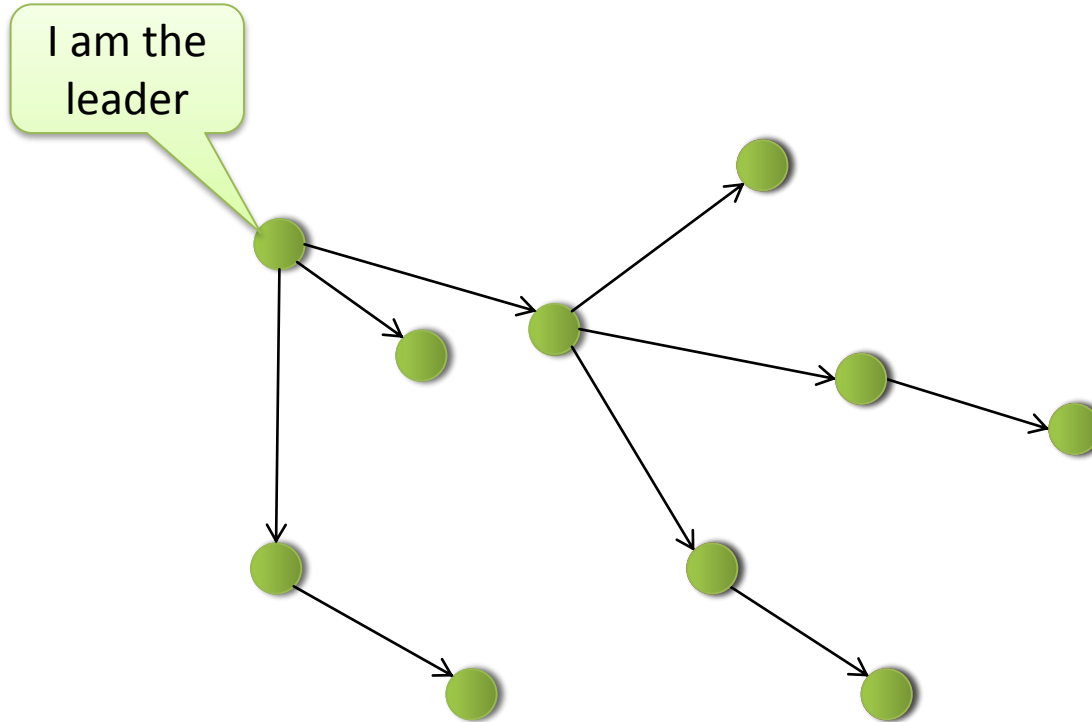
# Double-spending



# Double-spending in the Network



# Distributing the Bank

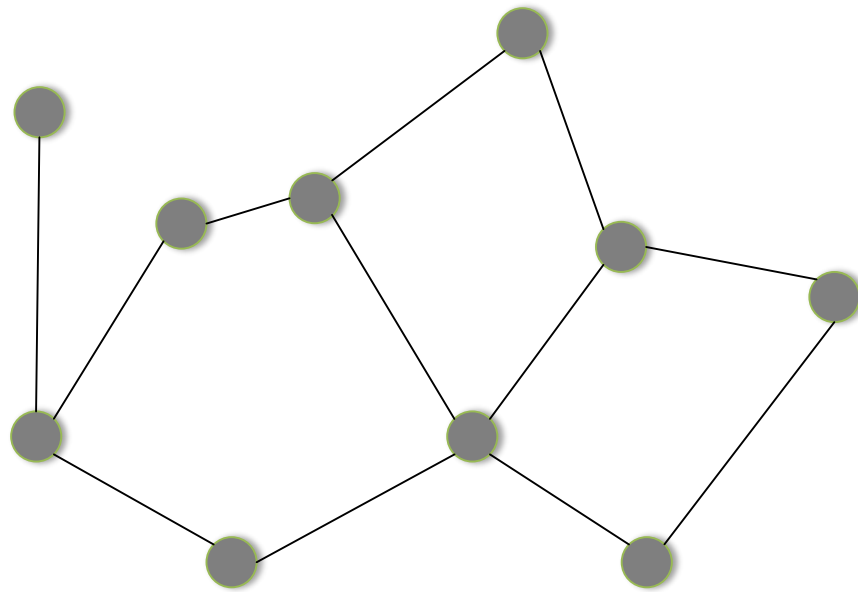


# Double-spending in the Real World

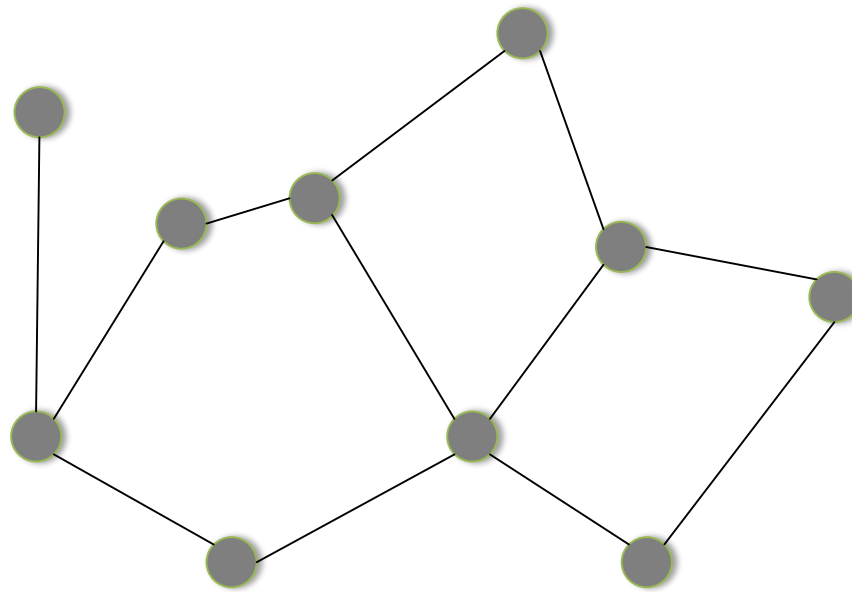
[Bamert, Decker, Elsen, W, Welten, 2013]



# Where would you inject your transaction?



# Double-spending, the Theory



Player 1: Where to inject original transaction?

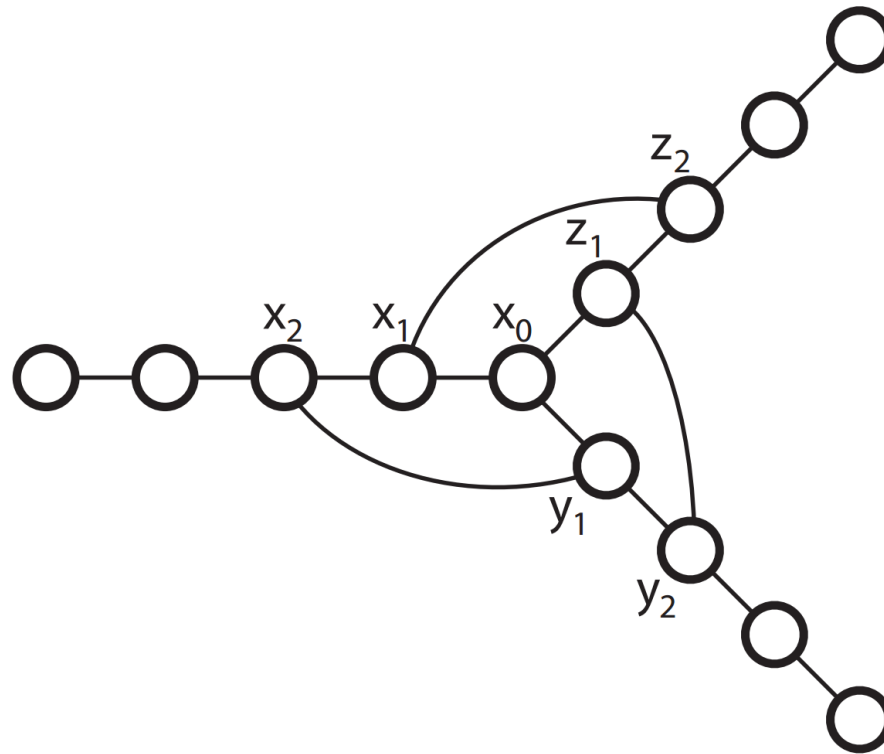
Player 2: Where to inject copy?



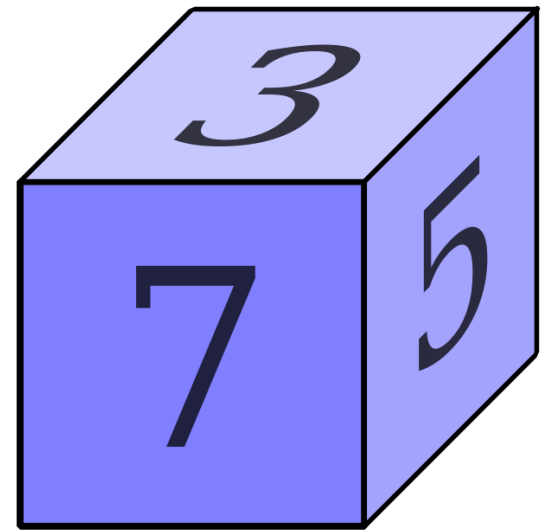
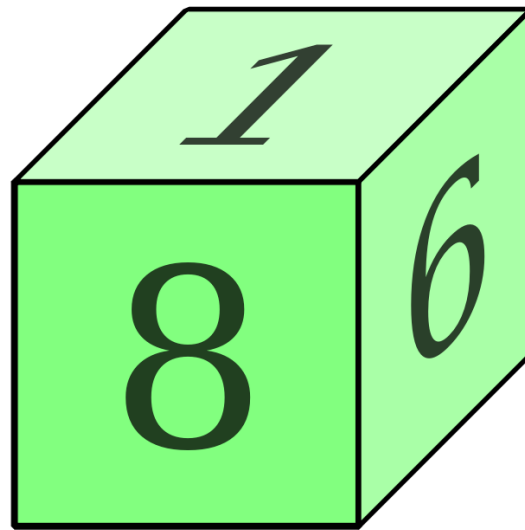
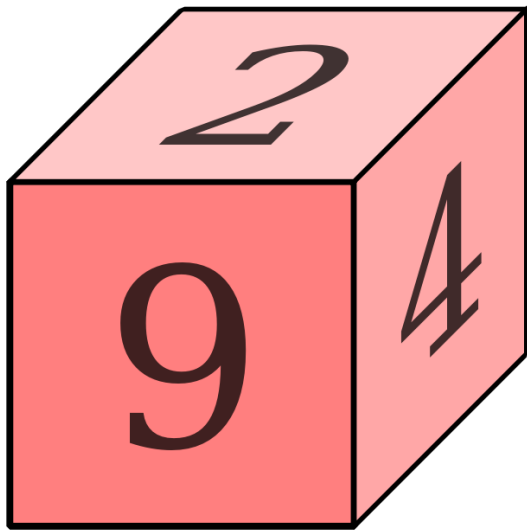
**SECOND IS  
THE FIRST  
LOSER**

Really?

# Sometimes, being second is better!



# Another Example: Nontransitive Dice



# Transaction Malleability

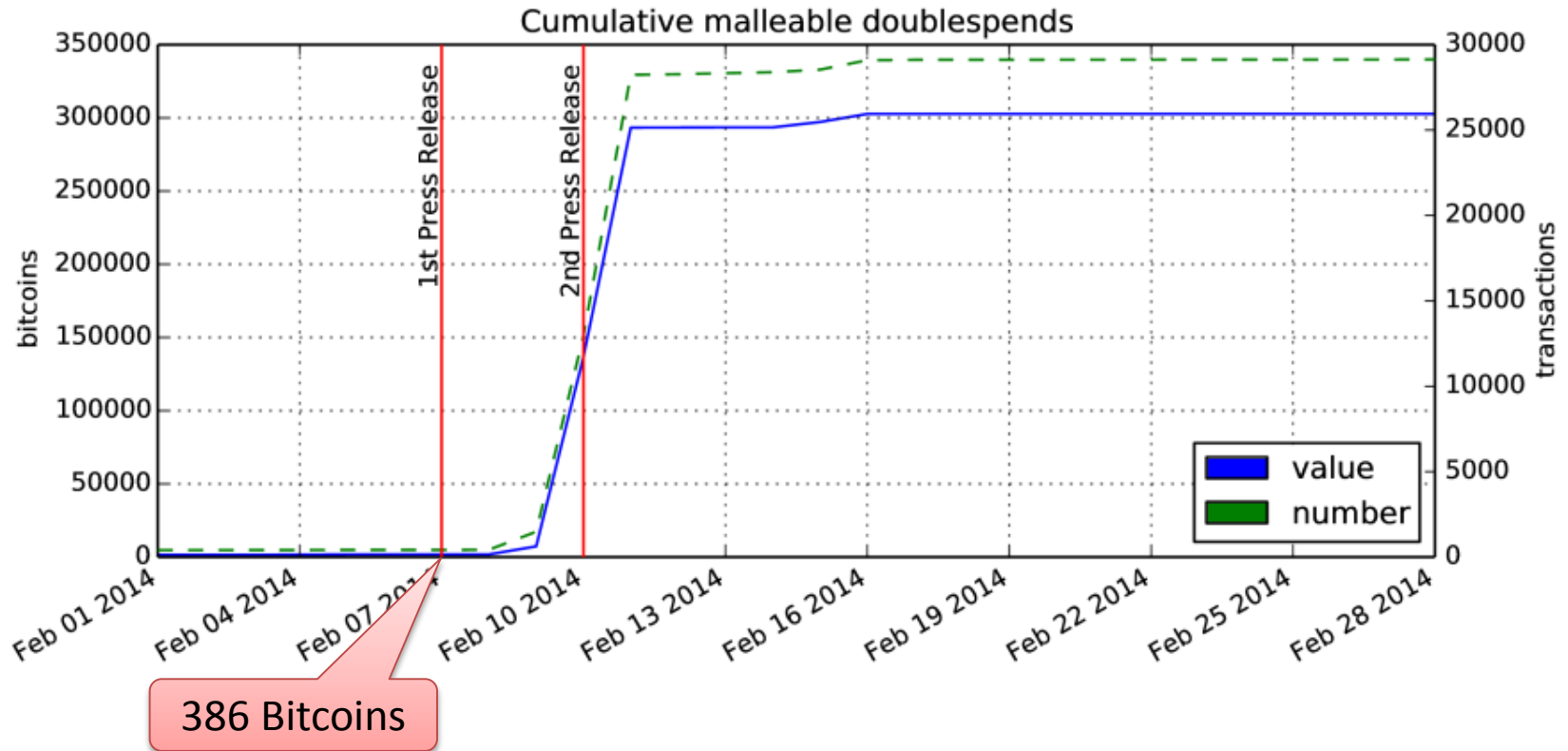


February 10, 2014: “Addressing Transaction Malleability: MtGox has detected unusual activity on its Bitcoin wallets and performed investigations during the past weeks.”

# Transaction Malleability



# Transaction Malleability in Real Life





**WHERE ARE THE**

**\$5000M, DUDE?**



# Summary



# Thank You!

Questions & Comments?

