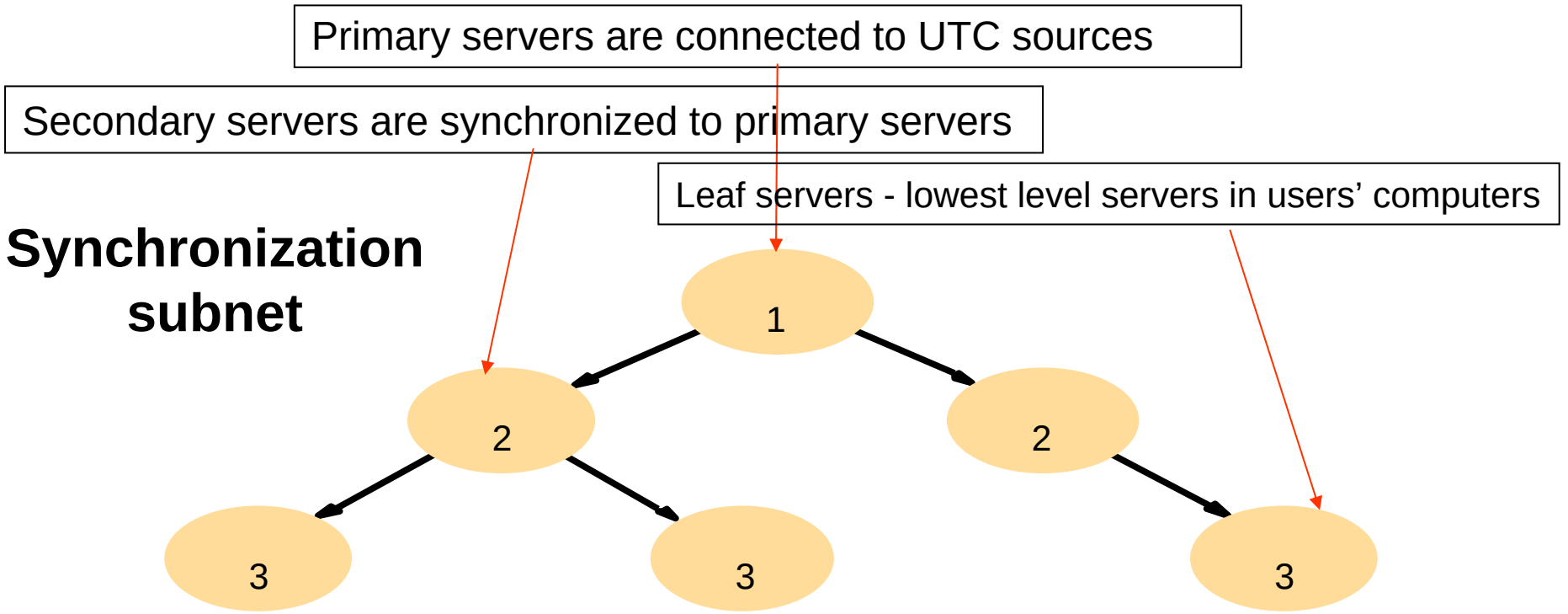
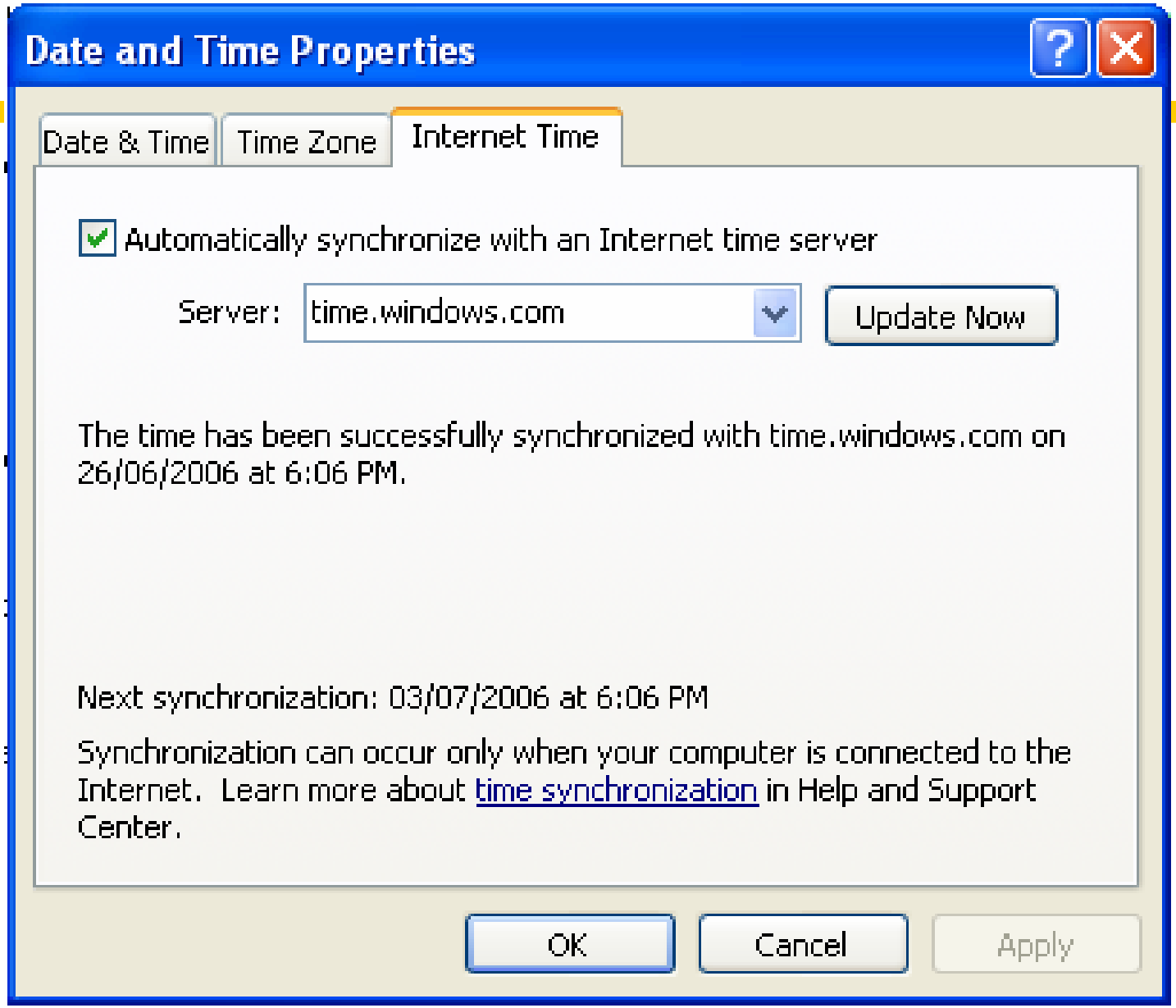
Network Time Protocol (NTP)

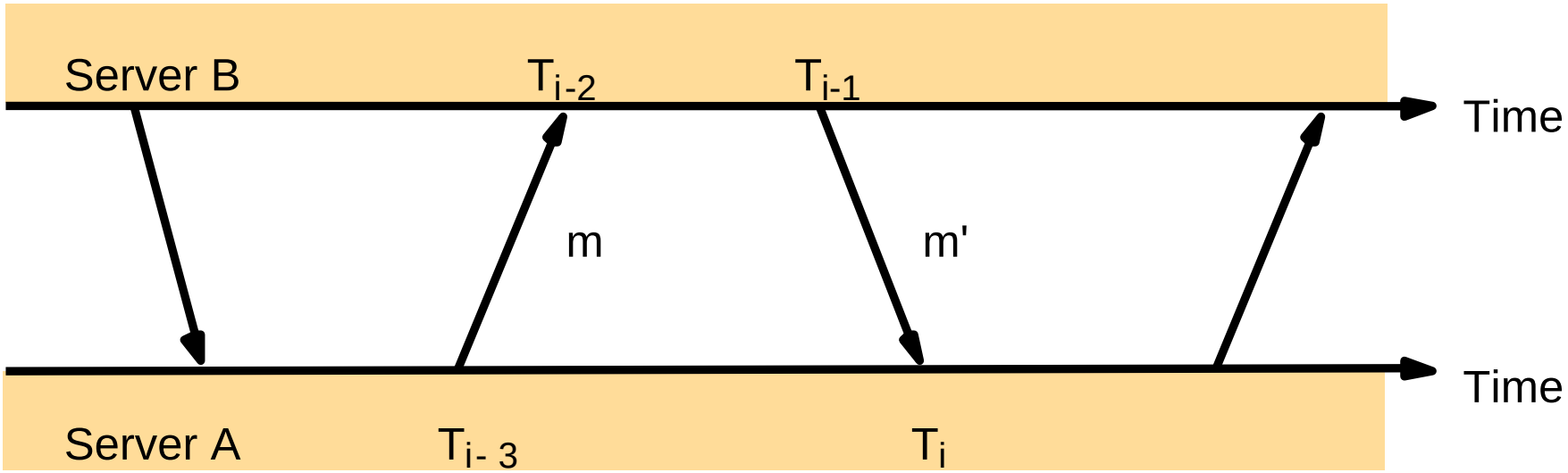
- The synchronization subnet can reconfigure if failures occur, e.g.
  - a primary that loses its UTC source can become a secondary
  - a secondary that loses its primary can use another primary




Date and Time Properties
Date & Time
Time Zone
Internet Time
Automatically synchronize with an Internet time server
Server:
time.windows.com
Update Now
The time has been successfully synchronized with time.windows.com on 26/06/2006 at 6:06 PM.
Next synchronization: 03/07/2006 at 6:06 PM
Synchronization can occur only when your computer is connected to the Internet. Learn more about time synchronization in Help and Support Center.
OK
Cancel
Apply

Messages exchanged between a pair of NTP peers

- Each message has timestamps of recent events:
  - Local times of *Send* and *Receive* of previous message
  - Local times of *Send* of current message



Accuracy of NTP

- For each pair of messages between two servers, NTP estimates an offset o, between the two clocks and a delay d_i (total time for the two messages, which take t and t')

  $T_{i-2} = T_{i-3} + t + o$ and $T_i = T_{i-1} + t' - o$
- This gives us (by adding the equations) :

  $d_i = t + t' = T_{i-2} - T_{i-3} + T_i - T_{i-1}$
- Also (by subtracting the equations)

  $o = o_i + (t' - t)/2$ where $o_i = (T_{i-2} - T_{i-3} + T_{i-1} - T_i)/2$
- Using the fact that t, $t'>0$ it can be shown that

  $o_i - d_i/2 \leqslant o \leqslant o_i + d_i/2$.
  - Thus o_i is an estimate of the offset and d_i is a measure of the accuracy
- NTP servers filter pairs $<o_i, d_i>$, estimating reliability from variation, allowing them to select peers
- Accuracy of 10s of millisecs over Internet paths (1 on LANs)