Event Order with Interval Timestamp in Event Correlation Service over Wireless Ad Hoc Networks

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INTRODUCTION

Event correlation is becoming important in event-based middleware. It allows subscribers in a publish/subscribe system to consume patterns of events rather than individual primitive events. These composite events flow among event broker grids over heterogeneous network environments. In wireless ad hoc network environments, temporal ordering and real-time issues are essential for event correlation. For example, to detect the direction of movement of an object, temporal ordering of events originating from different devices has to be determined. The event can be triggered by real-world phenomena, and PDA based auction applications are required to be real-time. We present two time related issues in event correlation: real-time temporal event ordering using interval timestamp, and interval-based semantics for event detection.

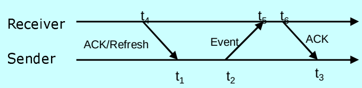
TEMPORAL MESSAGE ORDERING

Temporal ordering of events (**A** happened before **B**) from different devices and clocks has to be determined and real-time issues (**A** and **B** happened within a certain time interval) have to be solved. Existing time synchronization mechanism such as NTP expects good estimations for message delay that is not possible in wireless ad hoc networks. Constant time synchronization is too expensive in resource constrained environments. In our proposal an interval-based timestamp is embedded in each event. When a publisher node records an event in real-time it generates a timestamp, using its unsynchronized local clock, which is passed to other nodes. The interval-based timestamps consist of lower and upper bounds for the exact value, and they are transformed to the local time of the receiver node instead of adjusting the clocks. This process propagates until that the event reaches a subscriber node. The initial interval timestamp represents the event detection time, and generation must be inside the computer device, thus the interval timestamp at the publisher node must have zero length interval. Time transformation between the nodes is:

$$\Delta C(LocalClock) \rightarrow \left[\frac{\Delta C}{1+\rho_1}, \frac{\Delta C}{1-\rho_1}\right] \rightarrow \left[\Delta C\frac{1-\rho_2}{1+\rho_1}, \Delta C\frac{1+\rho_2}{1-\rho_1}\right]$$

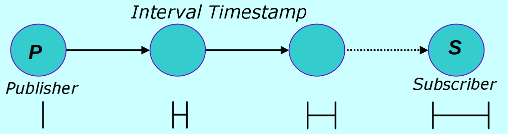
In wireless network environments, a constant message delay cannot be assumed since the network is highly dynamic. Thus, message delay has to be measured for each transferred message for accuracy. The round trip time (rtt: time passed from sending the event in the sender to arrival of the ACK in the event sender) using the local clock of the sender. Then the estimated message delay is transferred from sender to receiver by additional message exchange (an acknowledgement or control event for maintaining the state may be used with no overhead). The estimated delay for the event:

$$0 \le d \le (t_5 - t_4) - (t_2 - t_1)(1-\rho_r)/(1-\rho_s)$$



$$0 \le d \le (t_3 - t_2) - (t_6 - t_5)(1-\rho_s)/(1-\rho_r)$$

A timestamp is transformed from a publisher node to a subscriber along the chain of routing nodes.



Determine if **A** happened before **B**:

$$A[t_1^l, t_1^h] < B[t_2^l, t_2^h] = \begin{cases} Yes: t_1^h < t_2^l \\ No: t_2^h < t_1^l \\ Maybe: otherwise \end{cases}$$

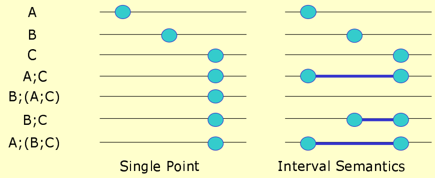
Determine if **A** and **B** happened within a certain real-time period R:

$$A[t_1^l, t_1^h] - B[t_2^l, t_2^h] < R = \begin{cases} Yes: \max(t_1^h, t_2^h) - \min(t_2^l, t_1^l) < R(1-\rho) \\ No: \max(t_1^l, t_2^l) - \min(t_2^h, t_1^h) < R(1+\rho) \\ Maybe: otherwise \end{cases}$$

EVENT DETECTION – INTERVAL SEMANTICS

We use interval-based semantics for composite event detection. A composite event for **A;B** (event **A** occurs before event **B**) has a duration which starts at primitive event **A** and ends at primitive event **B**. In single point detection, an instance of event **B;(A;C)** is detected if **A** occurs first, **B** followed by and **C**. With interval semantics, the sequence **A;B** can be defined to occur only if the intervals of A and B are non-overlapping. For example, a composite event **A;(B;C)** for snow weather where the humidity change requires before the temperature drop is detected with single point semantics incorrectly.

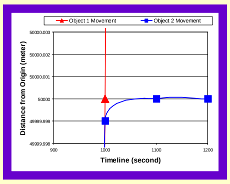
(**A:** move into the area above 1000m, **B:** temperature goes down to -4℃, **C:** humidity goes up to 80%)



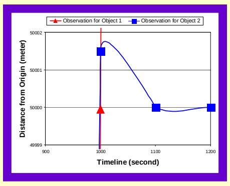
EVENT DETECTION – TEMPORAL RESTRICTION

Event **A** occurs within time unit t is denoted $\mathbf{A_t}$. In other word, **A** is valid for time unit t. An expression $\mathbf{(A;B_t)}$ or $\mathbf{(A;B)_t}$ defines a composite event when **A** is followed by **B** within t time units. Use of temporal restriction limits the number of instances of A to be kept for the detection of the composite event that works more efficiently in resource constrained environments.

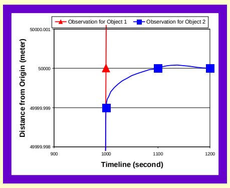
EXPERIMENT - OBJECT TRACKING



(a) Real Time



(b) With Drifted Clock



(c) Proposed Ordering

Movement of two objects is traced by smart devices surrounding the objects. Object 1 has linear movement with a constant speed of 50 meters per second. In contrast, object 2 has irregular speed. After 2000 seconds at a distance of 100 kilometers from the starting point, two objects meet each other. The average speed is about 180 kilometers per hour as strong wind or speedy cars. The observing smart devices have various clock drift. Maximum clock drift value 10^{-6} is used, and each device ranges (from 1 to 9)*10^{-7}. At start all the clocks are synchronized with real-time. There is no time synchronization process during the experiment, which lasts for about 30 minutes. Figures show the magnification of a section at 1000 seconds after the start where two object are in cloth distance. (a) shows that object 1 (▲) is ahead. The traced movement by the information from devices with drifted clocks is shown in (b) that depicts object 2 (■) leading to object 1, which conflicts the real time result. (c) shows the movement track by the proposed temporal ordering providing the correct result.

CONCLUSIONS

- Time related issues on event correlation over wireless ad hoc network environment, focusing on two subjects:
  - Real time temporal event ordering using interval-based timestamp
  - Interval-based semantics for event detection
- Proposed approaches will be a part of ongoing event brokering grid project.