Bridging WSNs to the Internet:
Issues on Event Filtering, Aggregation and Correlation

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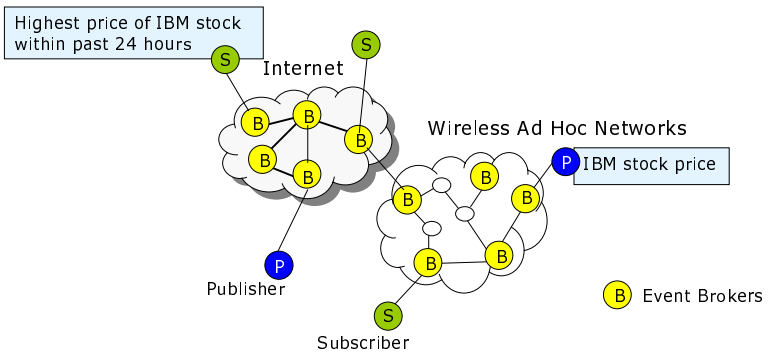
Event-Based Middleware

- Event-Based Middleware (Publish/Subscribe)
  - Many-to-many Asynchronous Communication
  - Event Correlation Support
- No Pure Wireless Ad Hoc: Connect to Internet



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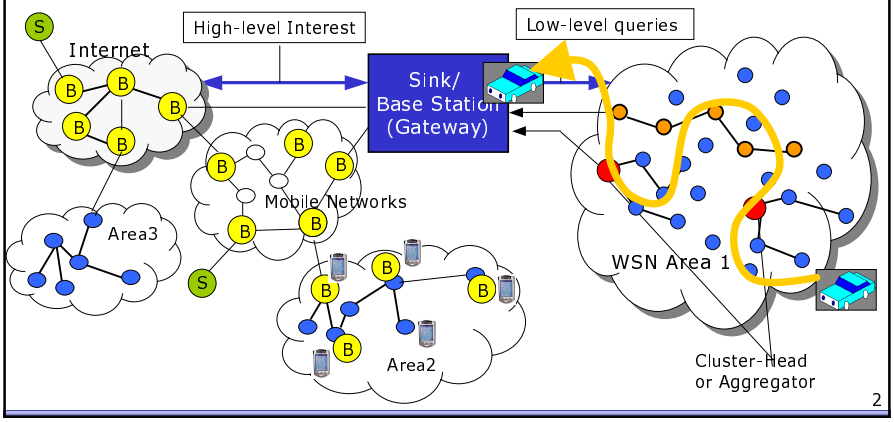
Emergence of WSN

- High Volume of Wireless Sensor Data
- Need to address Global Computing
- Recent Trend: Open API via Service Management



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Issues on Event Correlation

- No interoperable event correlation semantics
  - Various Correlation semantics
  - Consumption mechanism, Duplication Handling
  - Temporal correlation over distributed environments
  - Network Wide Correlation vs. In-Network Aggregation
    - TinyDB – Aggregation but no Handling of Duplication
    - TinyLIME – Filtering but no Aggregation
- Need to Defined Generic Semantics
  - Semantics and Parameters
- Wireless Networks Specifics
  - Memory Restriction, Other Resource Restriction
  - Real-Time (time of a real event occurrence)

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Unified Semantics for Event Correlation

- Event Model
  - Primitive events are instantaneous and atomic
  - Composite events based on composition algebra
  - Timestamp embedded (point-based, interval-based)
  - Spacestamp (location, groupID)
- Use of Event Algebra to Express Event Patterns
  - Well-defined semantics
  - Parameters to restrict basic expressions
- Define Algebra in Two Steps
  - Algebra Operation
  - Restriction Policy for individual composite event
    - Consumption Policy, Subset Policy, Precision Policy
- Support Interval-semantics

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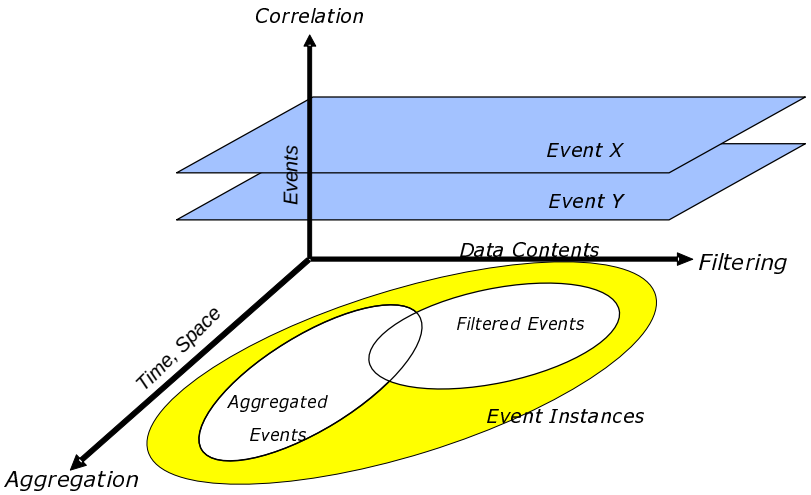
Filtering, Aggregation, and Correlation

- Composite events represent complex patterns of activity from distributed systems



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Event Correlation Basic Operators

Conjunction: A+B	Iteration: A*
Disjunction: A | B	Negation: –A
Concatenation: A B	Selection: A^N
Sequence: A ; B	Spatial Restriction: A_S
Concurrency: A||B	Temporal Restriction: A_T

Example: Two sensors are placed before (B) and after (A) the stop signs on the road.

- $(B;A)_2$: a car did not make full stop at the stop sign

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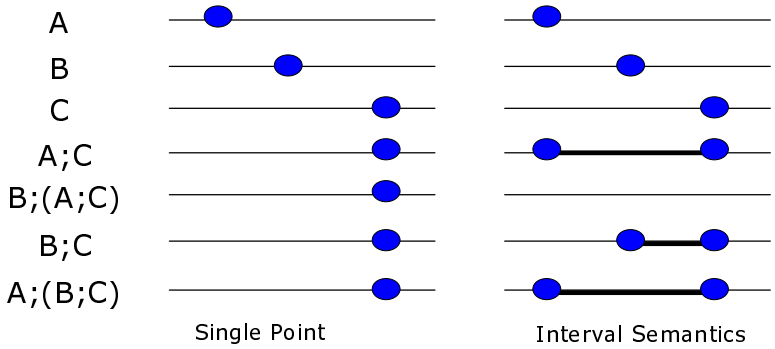
Interval Semantics

- Use Interval Semantics not Point Detection Time
- Composite Event: Occurrence Interval

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



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Temporal Conditions for Composite Events

Relation	Timestamps of Primitive Events	Point	Interval
A before B	P-P: $t_p(A) < t_p(B)$ I-I: $t_i(A)^h < t_i(B)^l$	○ A ○ B	○–A–○ ○–B–○
(A + B)		●–●	●———●
(A | B)		●	●——●
(A ; B)		●–●	●———●
A overlaps B	P-P: NA I-I: $(t_i(A)^l < t_i(B)^l) \wedge (t_i(A)^h > t_i(B)^l)$		○—-A—-○ ○—-B—○
(A + B)			●———●
(A | B)			●——●
(A B)			●———●

- Define Precisely Complex Timing Constraints
  - Relations (before, meets, overlaps, finishes, includes, starts, equals)

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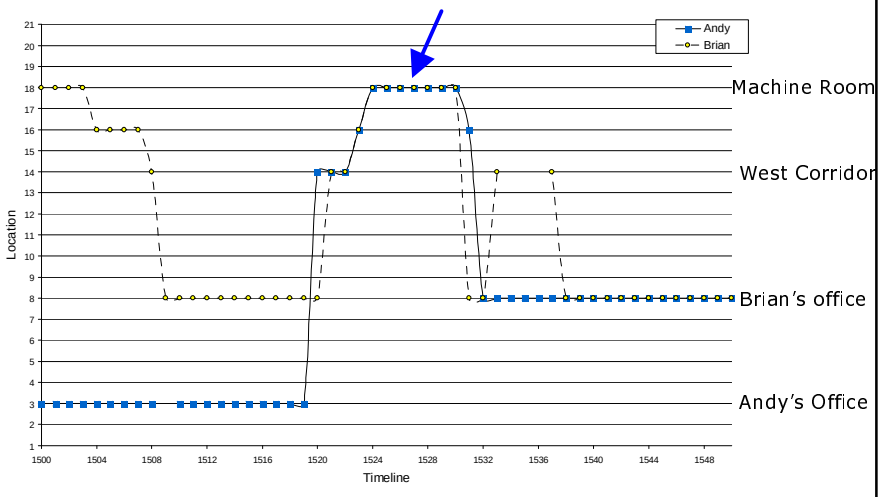
Experiment using Active BAT data

- Composite Event $(Andy_{60}+Brian_{60})_{machine\text{-}room}$



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Time Model

- W/ GPS and W/O GPS Coordinated Approach
- Use Interval-Based Timestamp for Inaccuracy

- W GPS:
  - NTP
- In W/O GPS Environments:
  - Lightweight Local Clock Propagation
    - Keep consistency at Aggregator/Sink nodes instead network-wide

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Conclusions and Future Work

- Unified Semantics for Event Correlation
  - Integrate Filtering, Aggregation and Correlation
  - Interval Semantics
  - Control Event Stream by Policies and Parameters

- Future Work
  - Complete Event Detection Algorithm
  - Integrate with Event Broker Grids
  - Algebra Transformation
    - Create reusable services for composite events
    - Adjust to Device Specific Constraints
    - Transform Complex Expression to Detectable Expression with limited resource

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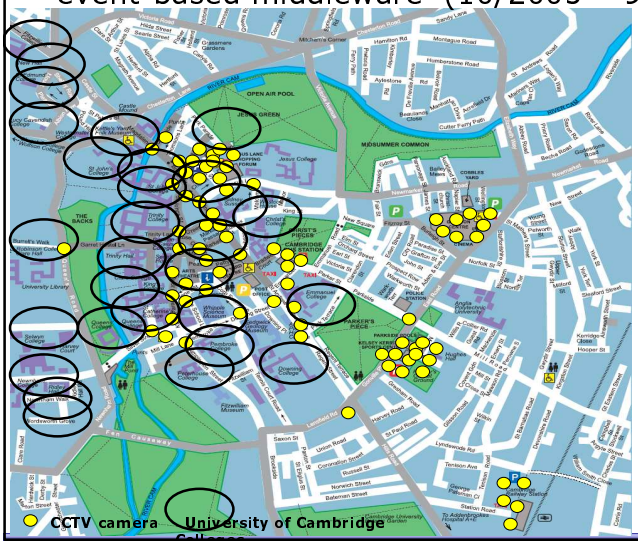
TIME (Transport Information Monitoring Environment)

- Integrate heterogeneous sensor networks into a event-based middleware (10/2005 – 9/2010)



Existing sensors:
- CCTV
- GPS on Bus
- Traffic Signal
- Car Parks
- Pedestrian Cross

New addition:
- GPS on Vehicles
- RF tags
- Video Camera
- ……

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Thank you!
Questions?

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