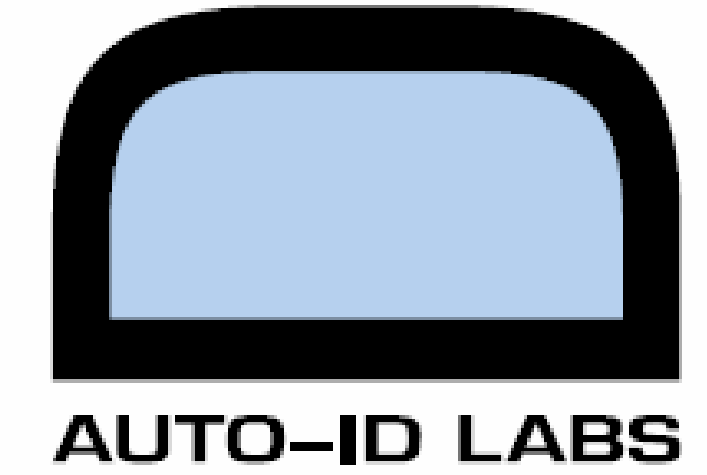


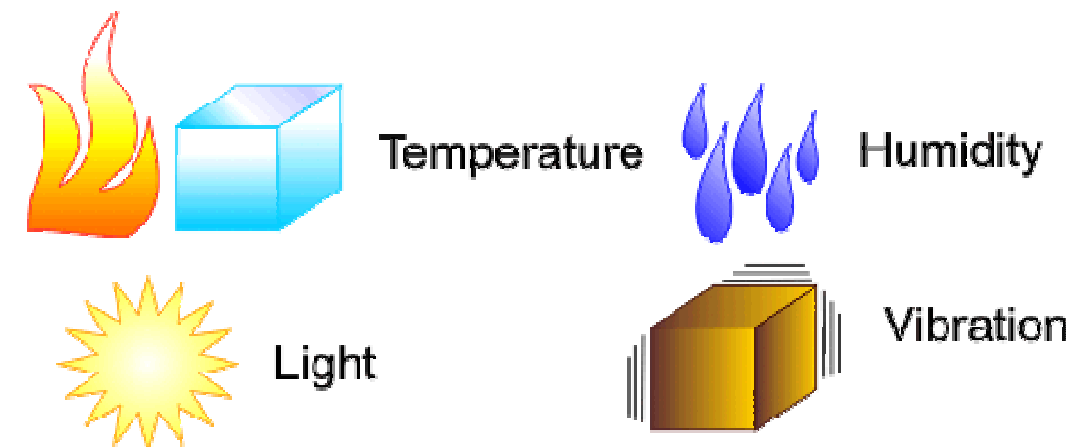


# Sensor Event Handling



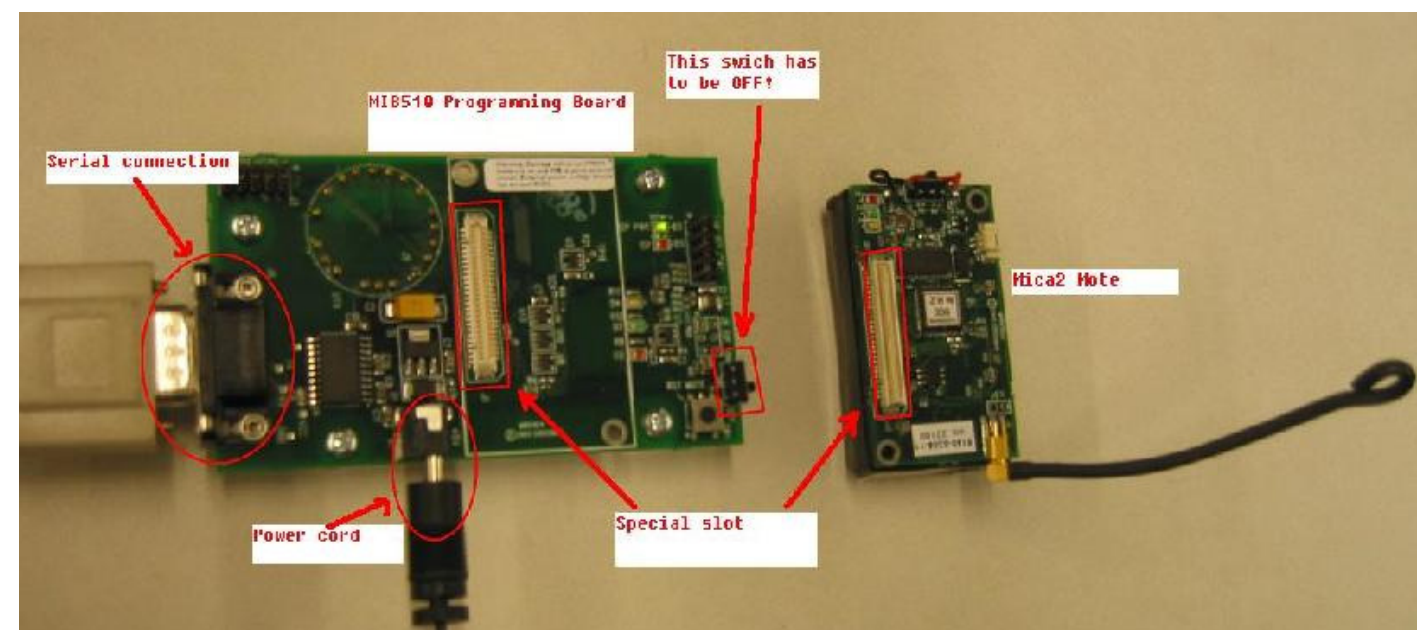
## Sensing Hardware

### Modes



Sensing modes include temperature, ambient light, humidity and vibration

### Hardware

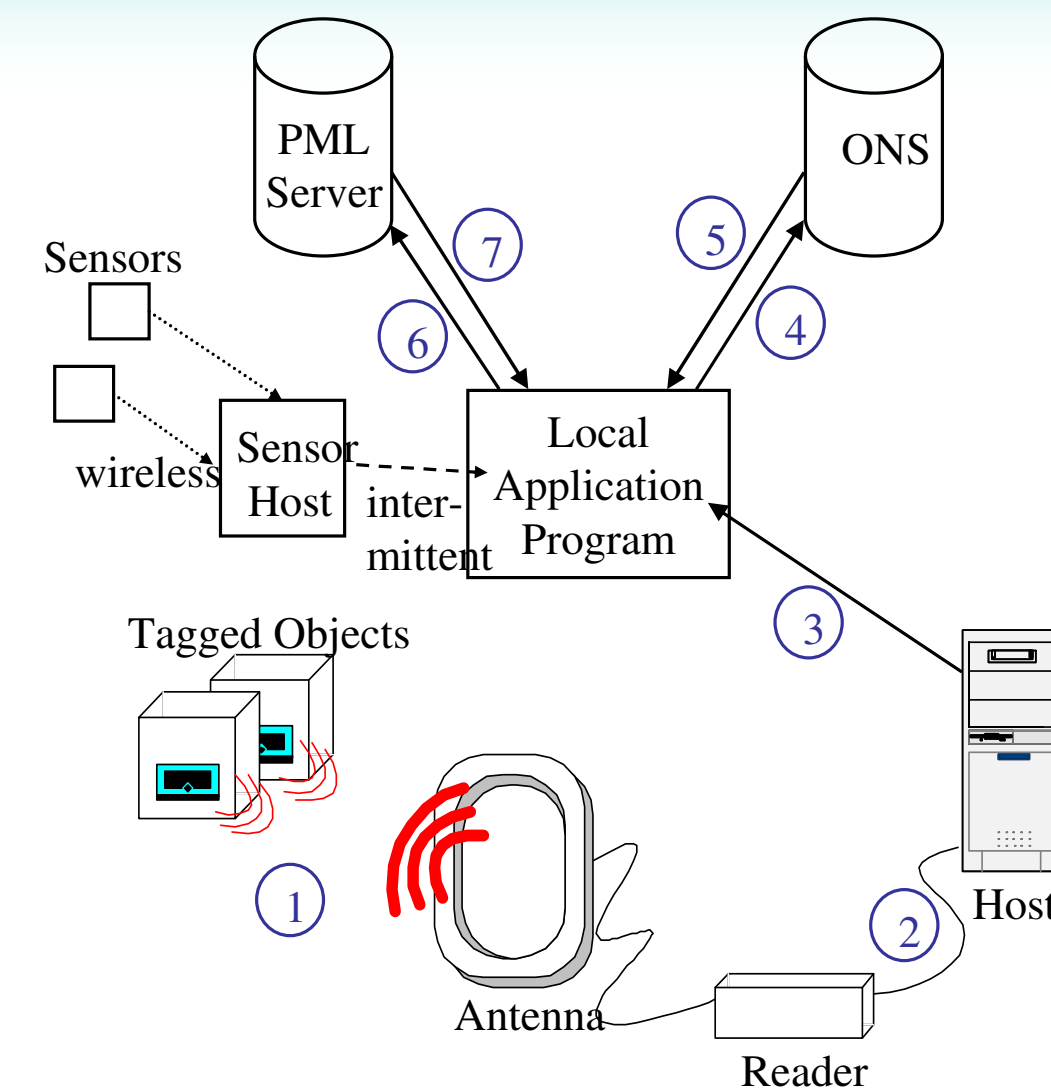


- Connect wirelessly to Sensor Host Machine, which collects data streams from sensor network queries.
- Sensor Host transmits data streams to Local Application Program for higher-level query processing.
- Sensors contain EPC unique identifier. Algorithms for both 2D and 3D modeling
- Readers obtain sensors reads then pass this to sensor event middleware.
- Middleware performs low-level read event filtering and passes read event streams to Local Application Program

By Kevin Emery, Samuel Madden, Stephen Miles and David Brock, MIT Auto-ID Laboratory

## Sensing Infrastructure

### Architecture



### Events

#### EPC Events

- A tag read event is lowest level RFID event.
- It is a stream  $\langle \text{tag\_id}, \text{reader\_id}, \text{time} \rangle$ .
- Consider the query for all tag reads. The operator tree for this query is base case (root=leaf).

#### Sensor Events

- A sensor event involves a physical reading at some time.
- Sensor event stream example:  $\langle \text{temp}, \text{sensor\_id}, \text{time} \rangle$ .
- Key difference between Tag Read Event and Sensor event is that stream may be intermittent: sensor readings taken in transit will be logged locally at the sensor host and then transmitted to the local application program when possible.

#### Business Events

- Idea is to construct operator trees on input streams that output useful business events. These run on the Local Application Program.
- Low-level events such as all tag reads output too much data and are difficult to use when making business decisions.
- High-level business events such as Shipment Reconciliation and ASN require complex operator trees but offer useful information.

### Data Layer

#### Streams and Relations

- Stream  $S$  defined as multi-set of tuples  $\langle s, t \rangle$  where  $s$  is the element added to  $S$  at time  $t$ .
- Relation  $R$  is a time-varying set of elements  $s$ . The elements of  $R$  at time  $t$  are given by  $R(t)$ .
- Primitive operators map streams to relations, relations to relations, and relations to streams.

#### Streaming Queries

- Streaming query defined as a tree of operators.
- Leaves are input streams and relations.
- Root is output node, producing either a stream or a relation.
- Each subtree defined recursively.
- Input streams produced by Savant and sensor host and transmitted to Local Application Program, on which the operator tree resides.

#### Events as Streaming Queries

- Event is defined as the output of a streaming query (i.e., the root node of the operator tree).
- Events  $e$  in a stream  $\langle e, t \rangle$  are described in PML.
- Event streams produced at the Local Application Program can then be transmitted over the WAN in SOAP messages to other business applications.

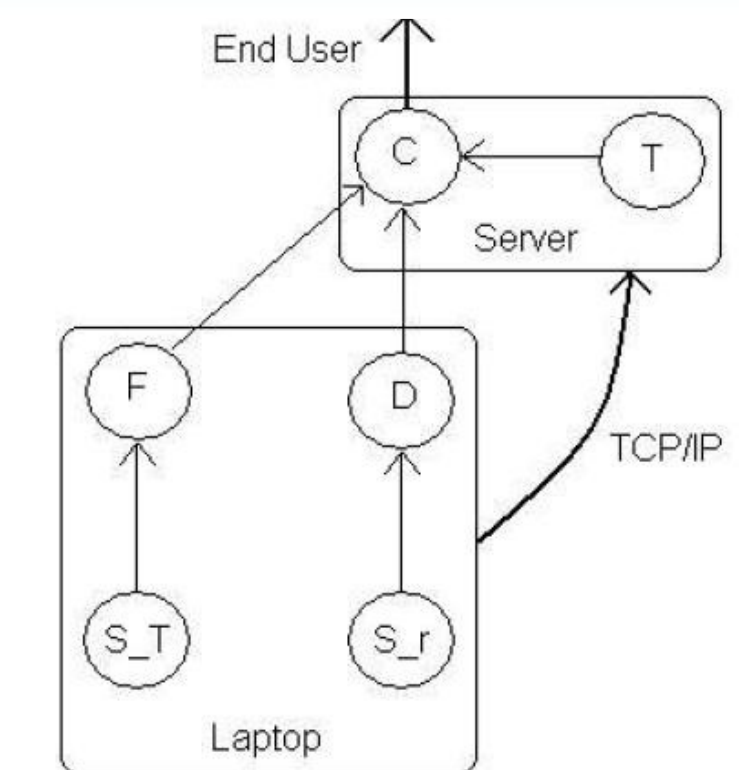
#### Filtering and Aggregation

- Exploit inference and differencing by sensing only changes in sensing state
- Use a data minimal *heartbeat* to indicate function
- Process data using a digital low-pass filter

Sponsors: EPCglobal, Altria, Intel, Raining Data and Reva Systems

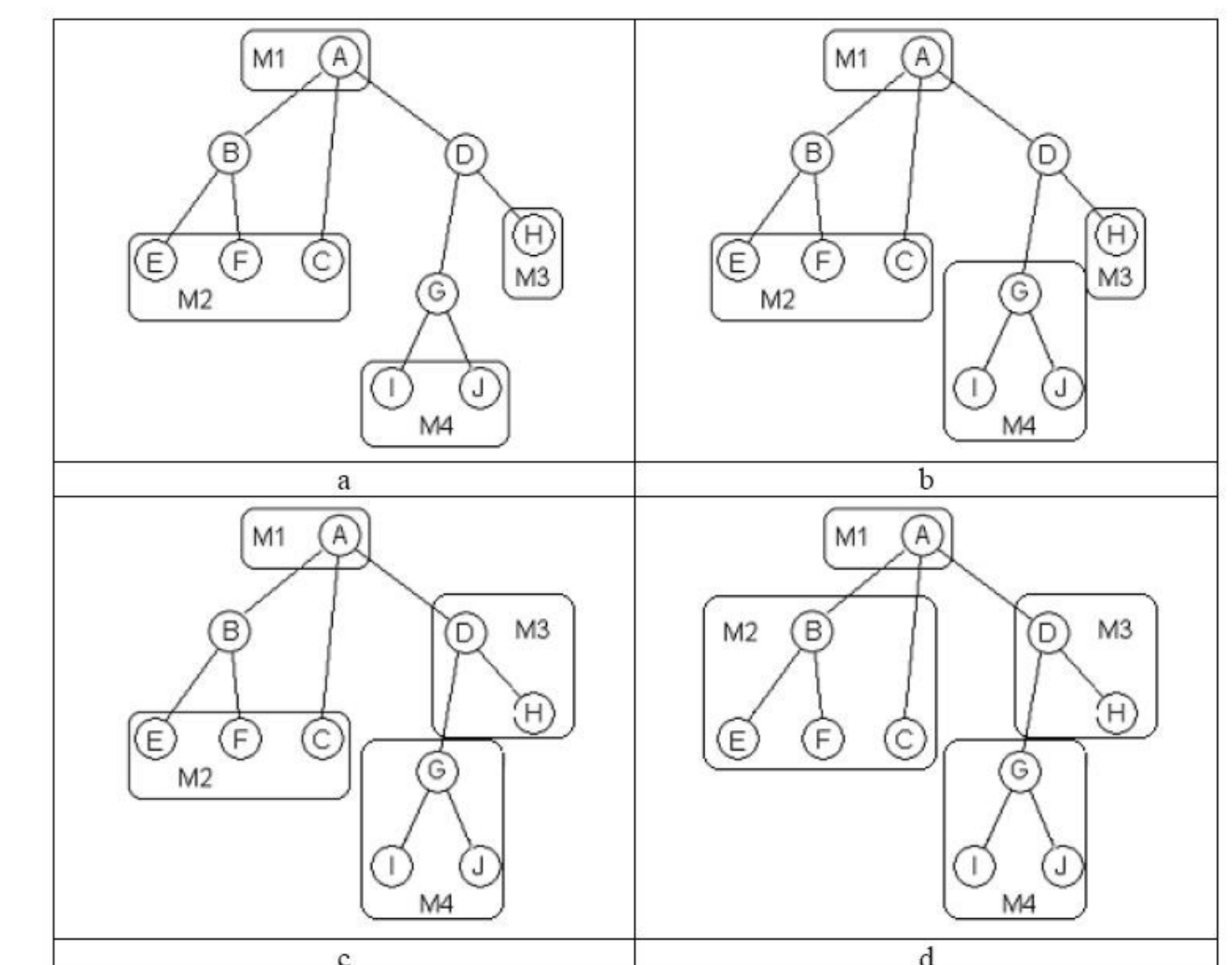
## Optimization

### Distributed Processing Network



The processing architecture for naïve cold-chain application. Laptop machine node contains query nodes ST, Sr, F, and D, which provide filtered RFID and sensor streams to the Server machine node. The Server contains global database T and cold-chain eventing application C.

### Migrating Processing Elements



Structural improvement algorithm operating on a query tree. Machines furthest down the query tree consume unassigned query nodes in an attempt to minimize machine edge traffic while obeying query node and machine capacity constraints.