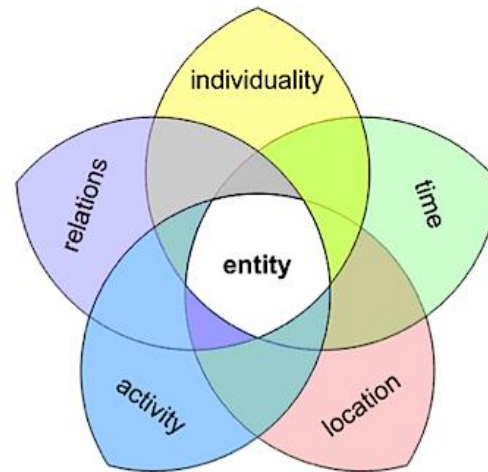


# Context Modeling

CMSC 818G Spring 2014

Peratham Wiriathamabhum

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**Fig. 1.** Five Fundamental Categories for Context Information

# A Data-oriented Survey of Context Models

Cristiana Bolchini, Carlo A. Curino, Elisa Quintarelli, Fabio A. Schreiber,  
Letizia Tanca

## In brief

- A comparison of context models with respect to a given target application - **metric**
  - With the stress on analysis of features
  - 2 folds
    - General framework analysis
    - Up-to-date comparison

# A Data-oriented Survey of Context Models

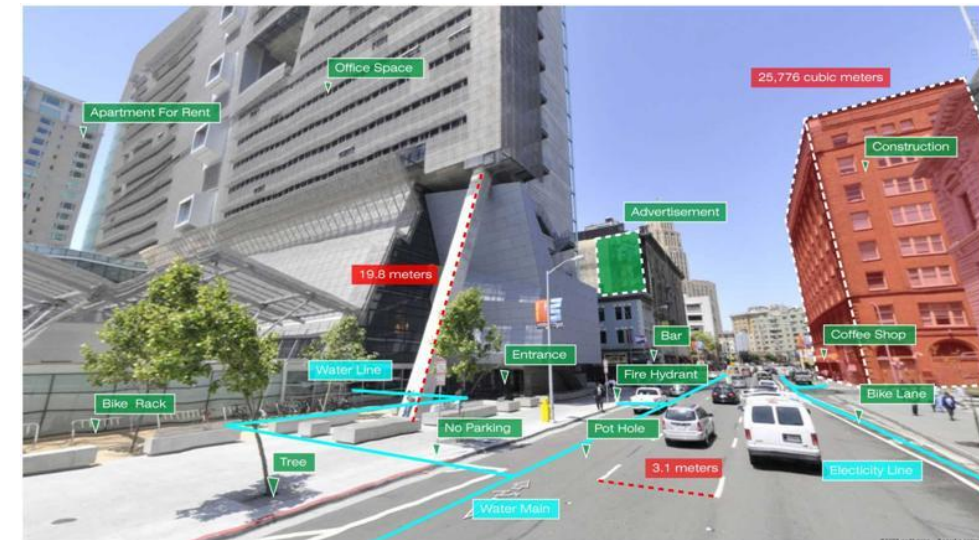
- Introduction
  - Context definition and context-aware applications
  - AI and context modeling
  - High-level architecture of a context-aware system
  - Context-based data tailoring
- The Analysis Framework
  - Model aspect
  - Representation features
  - Context management and usage
- The Context Models

# 1. Introduction

- Context definition and context-aware applications
- AI and context modeling
- High-level architecture of a context-aware system
- Context-based data tailoring

# Context definition and context-aware applications

- Context
  - Not just a profile but **an active process** dealing with the way humans weave their **experience** within their **whole environment**, to give it **meaning**.
  - Not just a state but **part of a process** where users are involved.
- General context models support context-aware applications
  - Adapt interfaces
  - Tailor the set of application-relevant data
  - Increase the precision of information retrieval
  - Discover services
  - Make the user interaction implicit
  - Build smart environments



# Ex. Automated support for a natural history museums visitors



- Adapting the UI to the **different abilities of the visitor**
  - Low-sighted people to a very young children
- Providing different information contents based on the **different interests/profiles of the visitor** and on **the room the visitor is currently in**
- Learning from **the visitor previous choice**. Try to predict which room the visitor is likely to visit next
- Providing the visitor with **appropriate services**
  - Purchase a ticket for a temporary exhibition to reserve a seat for the next in-door show
- Deriving **location information** from sensors which monitor the user environment
- Provide **active features** within the various areas of the museum, which **alert visitors with hints and stimuli on what is going on** in each particular ambient.

# AI and context modeling

- AI goal – context reasoning
  - Propositional logic
  - MultiContext System/Local Models Semantics
    - Linking multimodal knowledge sources
  - Semantic Web
- Require a different approach

$$\neg(A \wedge B) = \neg A \vee \neg B$$

$$\neg(A \vee B) = \neg A \wedge \neg B$$

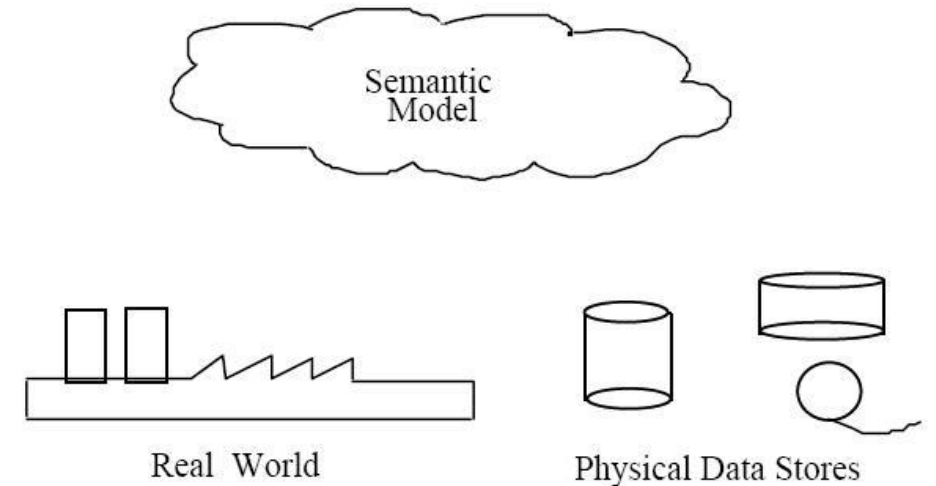
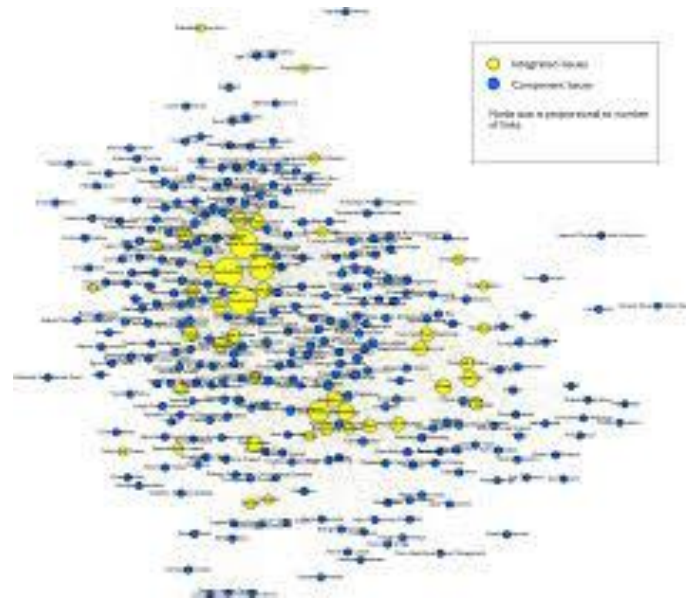
$$\neg(\neg A) = A$$

$$\neg(A \Rightarrow B) = A \wedge \neg B$$

$$A \Rightarrow B = \neg A \vee B$$

$$A \Leftrightarrow B = (A \wedge B) \vee (\neg A \wedge \neg B)$$

$$\neg(A \Leftrightarrow B) = (A \wedge \neg B) \vee (\neg A \wedge B)$$



# High-level architecture of a context-aware system

Modelling the elements that affect the knowledge/service/actions that have to be made available to the user at run-time when a context become available.

Context = Input/Output Switch

What portion of the entire information is **relevant** wrt. The ambient condition

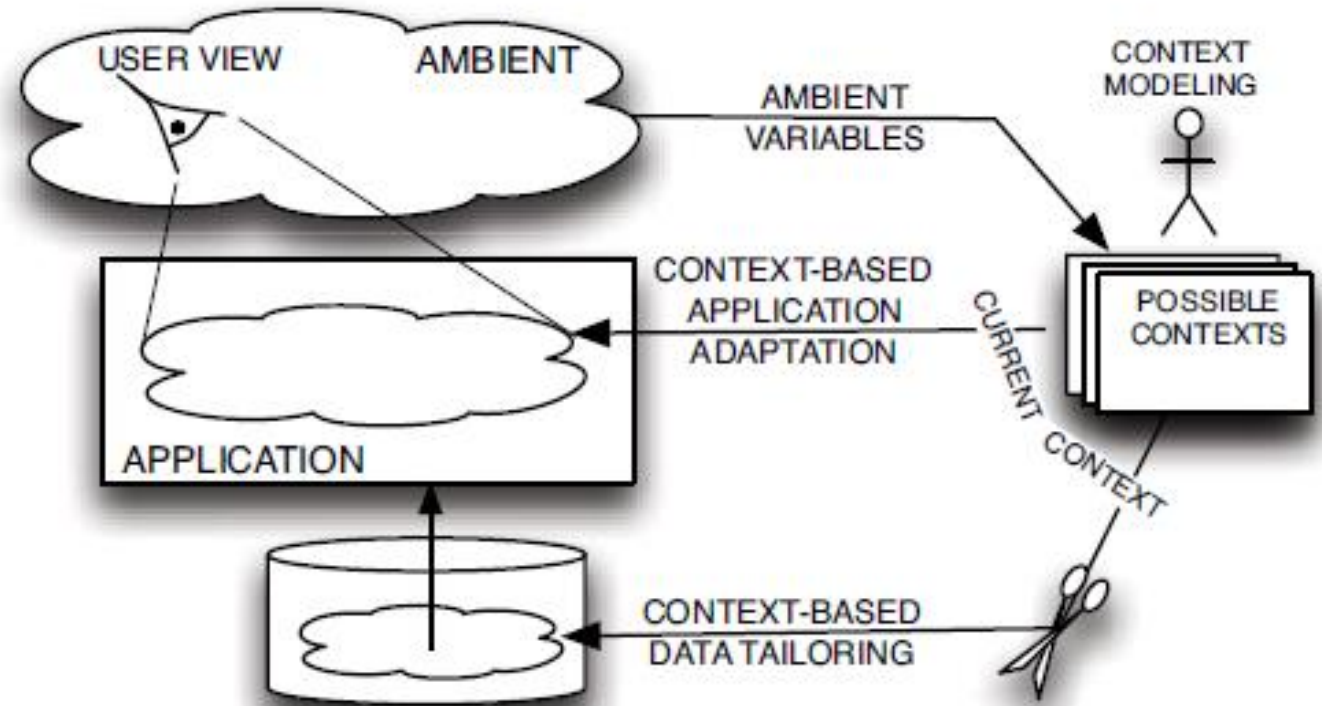


Figure 1: A context-aware system architecture

# Context-based data tailoring

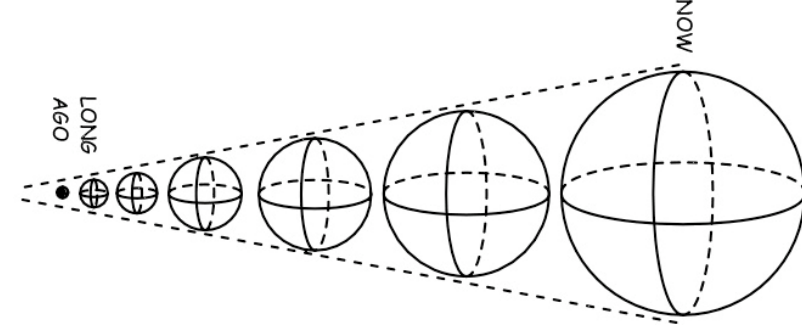


- Defining **data views** based on
  - the **identification of the various contexts** the application user is going to experience in the envisaged scenario
  - The **design of a set of data views** for each of the identified contexts.
- Filter the **relevant portion of data** in order to
  - provide the user with the **appropriately tailored set of data**
  - match devices' **physical constraints**
  - operate on a **manageable amount of data** (for improving query processing efficiency)
  - provide the user with **time- and location-relevant data** (mobile applications).

## 2. The Analysis Framework

- Define a set of **objectives** for comparison of which context model will be best suited with the goal
  - **Model aspect**
  - **Representation features**
  - **Context management and usage**
- Assume that the system designer follows 2 steps
  - **Identification of the key issues or features** for the application being developed – data tailoring (section 2)
  - **Select the best model** from the classification of the existing context models with respect to each feature based on step 1 (section 3)

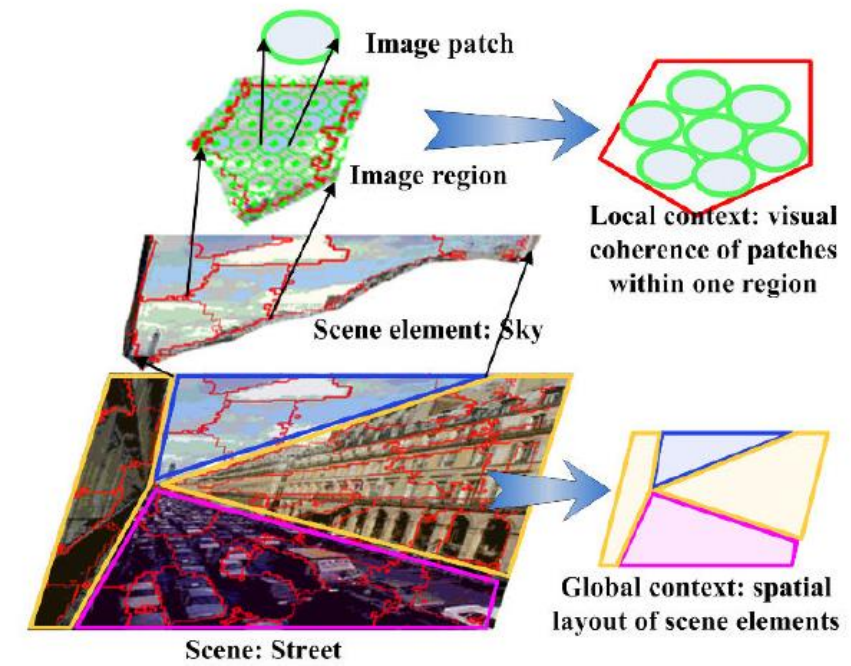
# Model aspect



- The set of context dimensions managed by the model.
  - Space
    - Location
  - Time
    - Temporal
  - Absolute/relative space and time
    - +? GMT, last month, near ?
  - Context history
    - Context depends on the previous context or just the current snapshot
  - Subject
    - The user itself
  - User profile
    - Preference, profile , role

# Representation features

- General characteristics of the model itself.
  - Type of formalism
    - Key-value, XML, logic, graph, ontology
  - Level of formality
    - Definition formalize the intuition
  - Flexibility
    - Adapt to different contexts, not application bounded
  - Variable Context Granularity
    - Different levels of details
  - Valid Context Constraints
    - Semantic constraints specific to the application



# Context management and usage

- The way the context is built, managed and exploited.
  - Context construction
    - Context description: design time/runtime
  - Context reasoning
    - Inference
  - Context information quality monitoring
    - E.g. sensors
  - Ambiguity and incompleteness management
    - Disambiguation
  - Automatic Learning Features
    - Learn user preference
  - Multi-Context Modeling
    - One model, all context



# 5 classes of uses / features grouping

- Context as a matter of
  - channel-device-presentation
  - location and environment
  - user activity
  - agreement and sharing (among groups of peers)
  - selecting relevant data, functionalities and services (data or functionality tailoring).

# 3. The Context Models

- Systems and supported features
  - See the table in the next slide →

| System          | Space | Time | Space/Time coordinates (Relative or Absolute) | Context history | Subject (User or Application) | User profile (Role or Features based) | Variable context granularity | Valid context constraints | Type of formalism: Key-value-based | Type of formalism: Mark-up based | Type of formalism: Logic-based | Type of formalism: Graph-based | Type of formalism: Ontology-based | Formality level (High or Low) | Flexibility | Context construction (Distributed or Centralized) | Context reasoning | Context quality monitoring | Ambiguity/Incompleteness mgmt. | Automatic learning features | Multi-context model |
|-----------------|-------|------|-----------------------------------------------|-----------------|-------------------------------|---------------------------------------|------------------------------|---------------------------|------------------------------------|----------------------------------|--------------------------------|--------------------------------|-----------------------------------|-------------------------------|-------------|---------------------------------------------------|-------------------|----------------------------|--------------------------------|-----------------------------|---------------------|
| ACTIVITY        | +     |      | A                                             | +               | U                             | F                                     | +                            |                           |                                    |                                  |                                | +                              |                                   | L                             | +           | C                                                 | +                 |                            |                                |                             | +                   |
| CASS            | +     | +    |                                               | +               | U                             |                                       |                              |                           |                                    |                                  |                                |                                |                                   | L                             | +           | D                                                 | +                 |                            |                                |                             |                     |
| CoBrA           | +     | +    | A                                             |                 | A                             | F                                     |                              |                           |                                    |                                  | +                              |                                | +                                 | H                             | +           | D                                                 | +                 |                            | +                              | +                           |                     |
| CoDaMoS         | +     | +    | R/A                                           |                 | A                             | F                                     |                              |                           |                                    |                                  |                                |                                | +                                 | H                             | +           | D                                                 | +                 | +                          |                                |                             |                     |
| COMANTO         | +     | +    | R/A                                           |                 | A                             | F                                     |                              |                           |                                    |                                  |                                |                                | +                                 | H                             | +           | D                                                 | +                 | +                          |                                |                             |                     |
| Context-ADDICT  | +     | +    | R/A                                           |                 | A                             | R                                     | +                            | +                         |                                    | +                                |                                | +                              | +                                 | H                             | +           | C                                                 | +                 |                            |                                |                             |                     |
| Conceptual-CM   | +     | +    | R                                             | +               | A                             | R                                     |                              |                           |                                    |                                  |                                | +                              |                                   | L                             | +           | C                                                 | +                 |                            | +                              | +                           | +                   |
| CSCP            |       |      |                                               |                 | A                             | F                                     |                              |                           |                                    | +                                |                                |                                |                                   | L                             |             | C                                                 |                   |                            | +                              | +                           | +                   |
| EXPDOC          |       | +    | R                                             | +               | U                             | F                                     |                              |                           |                                    |                                  | +                              | +                              |                                   | H                             |             | C                                                 |                   |                            | +                              | +                           | +                   |
| FAWIS           |       |      |                                               | +               | U                             | F                                     | +                            |                           | +                                  |                                  |                                |                                |                                   | H                             |             | C                                                 |                   |                            | +                              | +                           | +                   |
| Graphical-CM    | +     | +    | R                                             |                 | A                             | F                                     |                              |                           |                                    |                                  |                                | +                              |                                   | H                             | +           | C                                                 |                   | +                          | +                              | +                           | +                   |
| HIPS/HyperAudio | +     | +    | A                                             | +               | U                             | F                                     |                              |                           | +                                  |                                  |                                |                                |                                   | L                             |             | C                                                 | +                 |                            | +                              | +                           |                     |
| MAIS            | +     | +    | A                                             |                 | A                             | F                                     | +                            |                           |                                    |                                  |                                |                                | +                                 | H                             |             | C                                                 |                   |                            | +                              | +                           |                     |
| SCOPES          |       |      |                                               |                 | A                             |                                       |                              |                           |                                    |                                  | +                              |                                |                                   | H                             |             | D                                                 | +                 |                            | +                              |                             | +                   |
| SOCAM           | +     | +    | R/A                                           |                 | A                             | F                                     |                              |                           |                                    |                                  |                                |                                | +                                 | H                             | +           | D                                                 | +                 | +                          |                                |                             |                     |
| U-Learn         | +     | +    | A                                             |                 | U                             | F                                     |                              | +                         |                                    |                                  |                                |                                | +                                 | H                             | +           | D                                                 |                   | +                          |                                |                             | +                   |

# Conclusion

- Still no 'one context model system for all'
- The solution is based on application, no common solution
- define context | task → create data views

# Modeling context in pervasive computing systems

Karen Henricksen, Jadwiga Indulska, and Andry Rakotonirainy

# In brief

- The development of **appropriate context modeling concepts** for **pervasive** computing, which can **form the basis** for such a context management infrastructure - **concepts**
  - Overcomes problems associated with previous context models, including their **lack of formality and generality**, and also tackles issues such as **wide variations in information quality**, the existence of **complex relationships amongst context information** and **temporal aspects** of context.

# Modeling Context Information in Pervasive Computing Systems

- Motivation
- Defining Context
- Related Work
- Modeling Context Information

# 1. Motivation

- Pervasive computing
  - Cheap, interconnected computing devices are ubiquitous
  - Supporting users in a range of tasks
- The system should be capable of operating in
  - Highly dynamic environments
  - Placing fewer demands on user attention
  - OR sensitive on **context**
- **How to program a context-aware application?**
  - Common tasks: context modeling and management

## 2. Defining context

- 2.1 Case study : communication applications
  - Bob has finished reviewing a paper for Alice and would like to **share his comments**.
  - Bob instructs his **communication agent** to **initiate a discussion** with Alice.
  - Alice **is in a meeting** with a student, so her agent determines on her behalf that she **should not be interrupted**.
  - The agent recommends that Bob either contact Alice by **email** or **meet with her in half an hour**.
  - Bob's agent consults his **schedule**, and, realizing that he is **not available** at the time suggested by Alice's agent, **prompts Bob to compose an email** on the **workstation** he is currently using, and **then dispatches it** according to the instructions of Alice's agent.



## 2. Defining context

- 2.1 Case study : communication applications
  - A few minutes later, Alice's **supervisor**, Charles, wants to know whether the report he has requested is ready. Alice's agent decides that the query needs to be answered **immediately**, and suggests that Charles **telephone** her on her office number. Charles' agent establishes the call using **the mobile phone** that Charles is carrying with him.



## 2.1 Case study : communication applications

- Agents are relied upon the informations of...
  - The participants
    - Knowledge about the participant's activities
    - Relationships between peoples - X supervised Y
  - The communication devices
    - Owned devices and availability of them
    - Channels and devices to use
- These information can be collected from...
  - Explicit inputs by users - diary
  - Sensors – location sensor



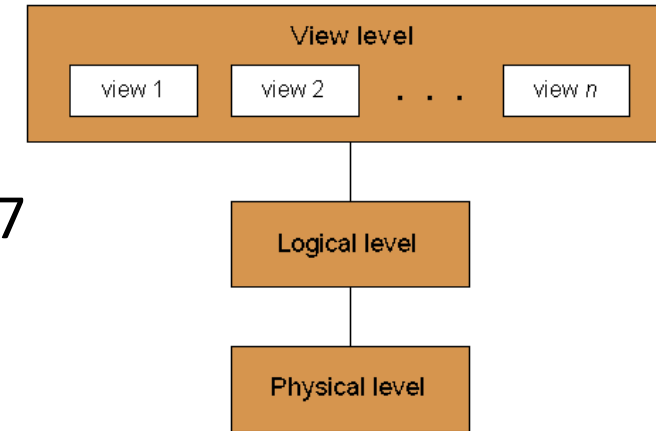
## 2.2 Characteristics of context Information

- Context Information Exhibits a Range of **Temporal** Characteristics
  - Pervasive systems are characterized by **frequent** changes (dynamics) - sensors
    - Duration varies - colleagues (months), location (minutes)
  - Reasonable to acquire **static** informations from **user input** – birthday
- Context Information is **Imperfect**
  - may be incorrect or ambiguous –
    - sensors fault
    - out-of-date information from a highly dynamic nature
    - disconnections/failures



## 2.2 Characteristics of context Information

- Context Has **Many Alternative Representations**
  - sensor output like GPS to app level knowledge like CSIC 2107
  - Many levels of abstractions
- Context Information is **Highly Interrelated**
  - Relationships between people, devices and channels
  - Derivations – derive current activity by past locations and past activities
    - The **quality** of the derived information depends on the source information to be derived



## 2.3 Context Modeling and Management for Pervasive Systems: Requirements

- How to represent and manage context information?
  - Neither DBMS nor Object-oriented programming language are appropriate
  - When the authors try to model the 'case' in section 2.1 with ER or UML,
    - Difficulties in distinguishing between different classes of context information – static/dynamic, sensor/input
    - UML is better than ER but still cumbersome
  - The authors suggest using a special construct design with context characteristics in mind



### 3. Related work

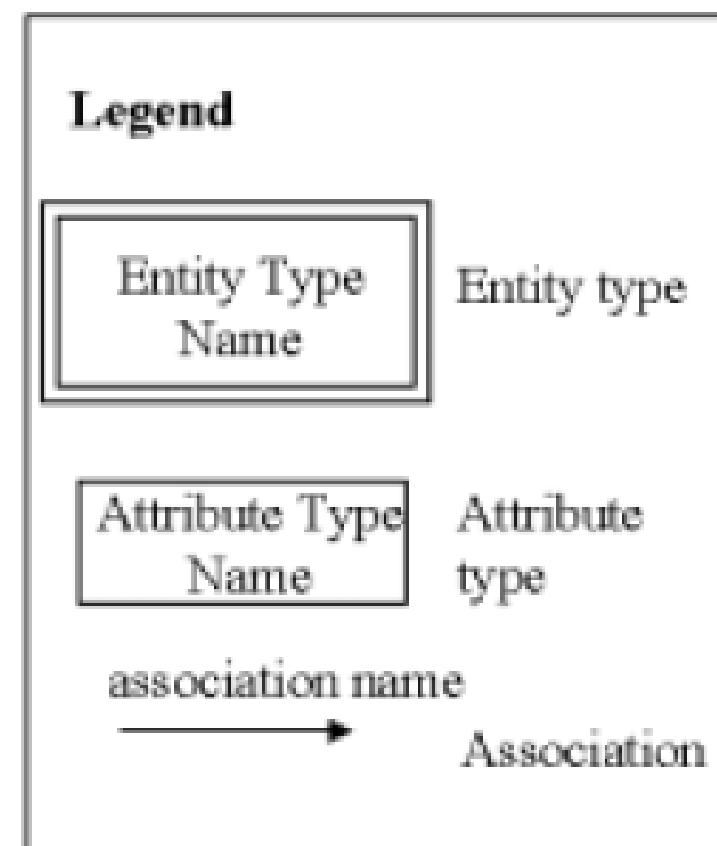
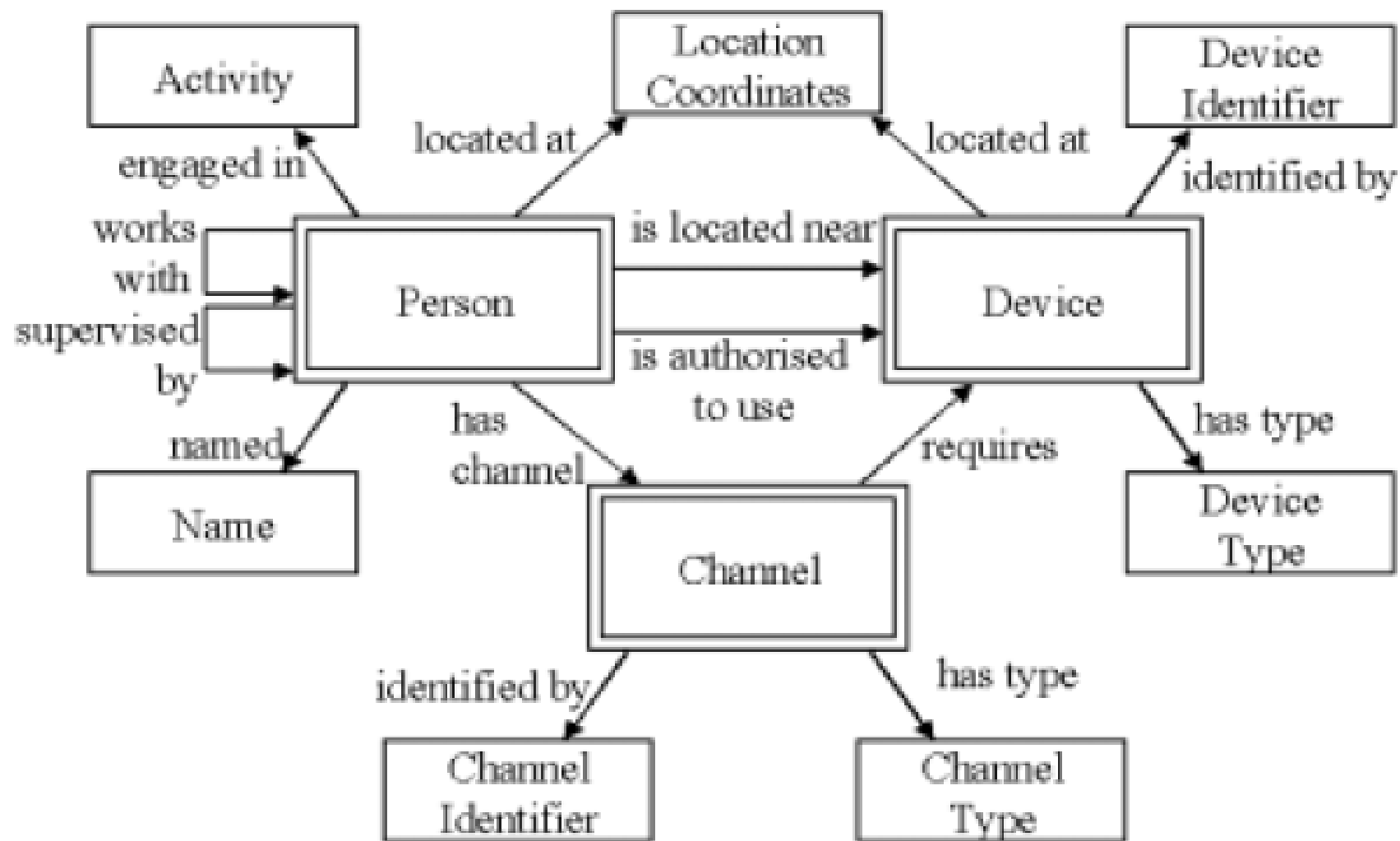
- 2 types of frameworks
  - Support the abstraction of context information from sensors
  - High-level models of context information that can be queried by apps
- Short comings
  - Lack the formal basis to capture the context in an unambiguous way and support reasoning
  - Restricted to narrow class of context, only sensed information and derivatives, no temporal or context histories
  - Does not address context quality

## 4. Modeling context information

- Core Modeling Concepts
- Classifying Associations
- Structural Constraints on Associations
- Modeling Dependencies
- Modeling Context Quality

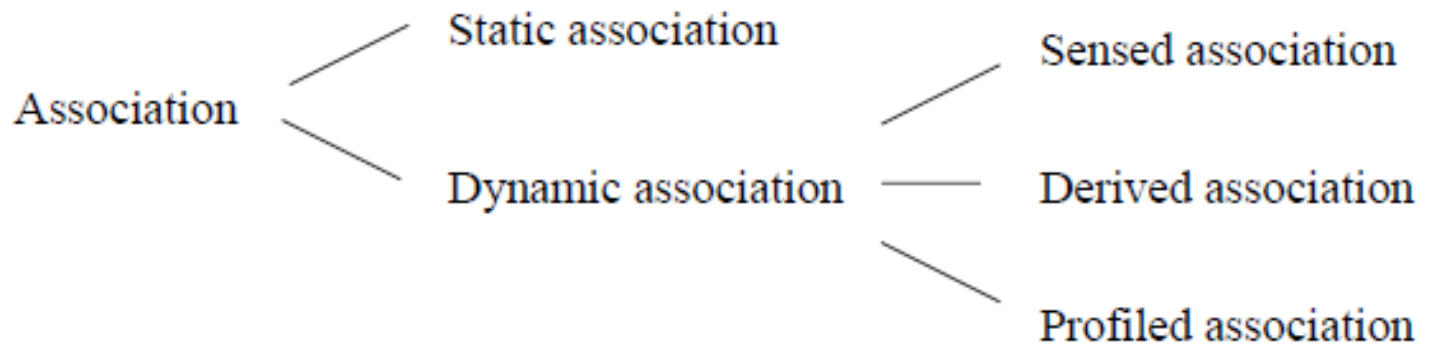
## 4.1 Core modeling concepts

- Nodes
  - ○ entities – person, communication channel
  - ○ attributes – name, identifier of communication channel
- Directed edges
  - → associations – linking entities/attributes
    - A own B =  $A \rightarrow B$



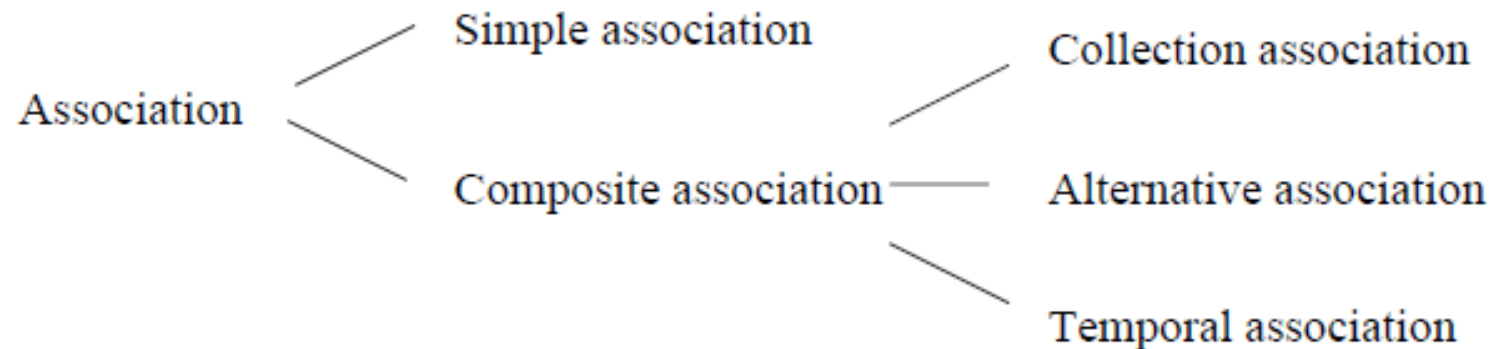
## 4.2 Classifying associations

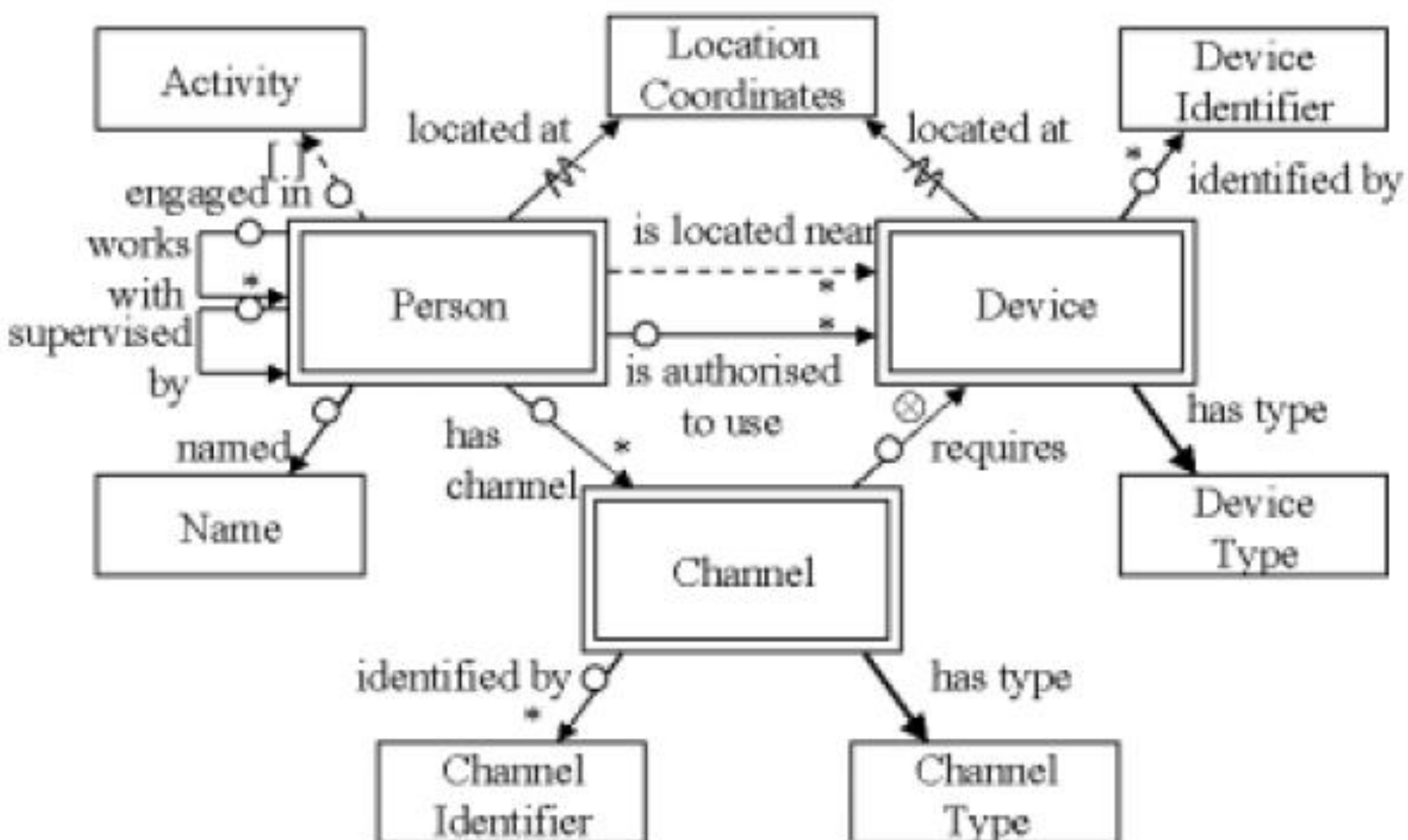
- Static = the relations are fixed for the lifetime of the entities
  - Relationship over devices, channels
- Dynamic =  $\sim$ static
  - Can be further classified based on source
    - GPS
    - Near?
    - Works with X
- Help reasoning



## 4.3 Structural Constraints on Associations

- Simple, atomic facts to complex histories
- Simple = entity participates 1 time or less
- Composite =  $\sim$ simple
  - Collective – one entity to many entities/attributes
  - Alternative – one entity to one of many entities/attributes
  - Temporal – one entity to X in time interval



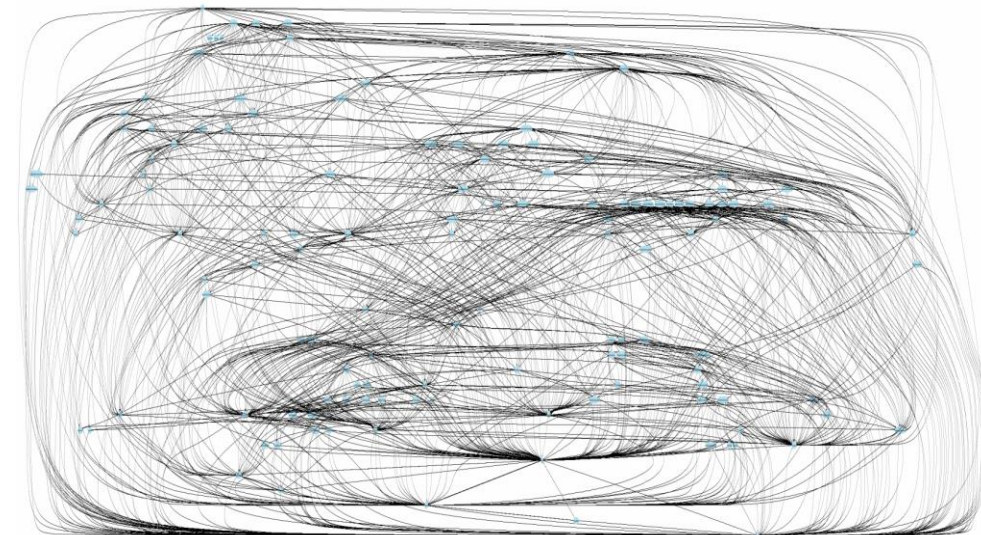


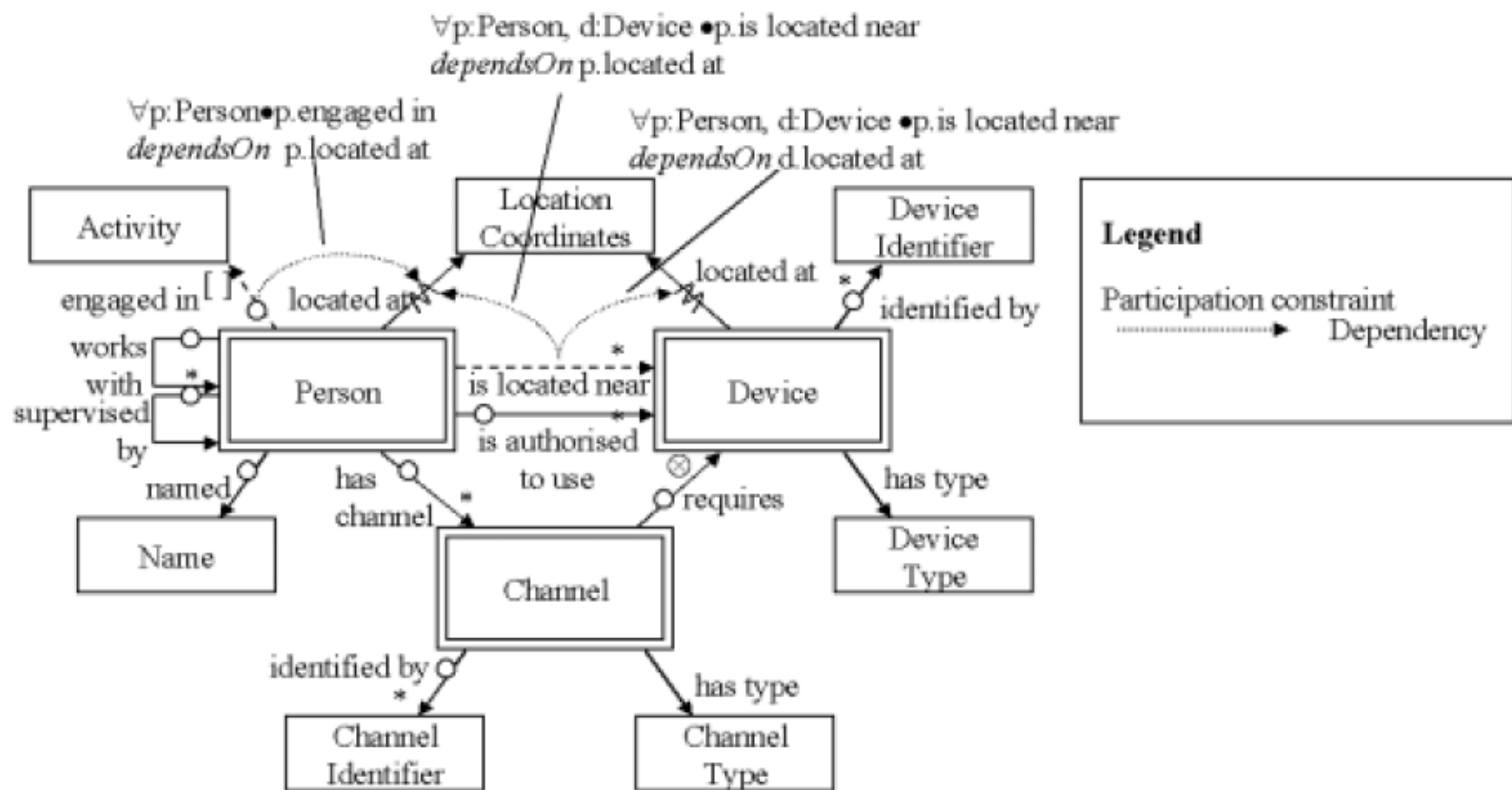
### Legend

- Static association
- - - - - Derived association
- → Profiled association
- AA → Sensed association
- Simple association
- \* Collection association
- ⊗ Alternative association
- [ ] Temporal association

## 4.4 Modeling Dependencies

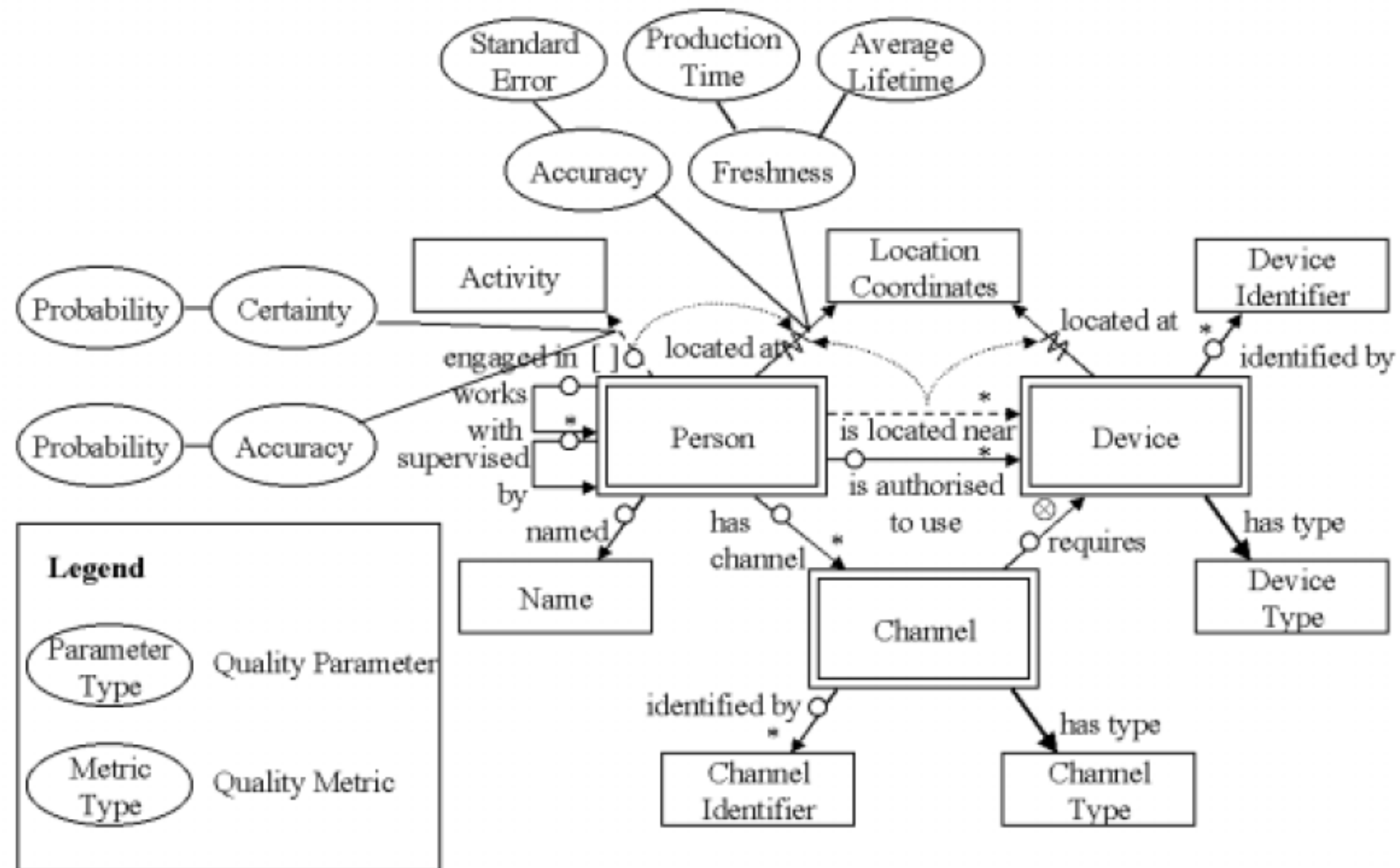
- Association A depends on Association B
  - Correlate – B changes  $\rightarrow$  A changes (by some potential)
    - Battery life  $\rightarrow$  Bandwidth
    - Location of person  $\rightarrow$  Location of device
- Help improve stability
  - Can detect out-of-date context information





## 4.5 Modeling Context Quality

- Context information are not perfect
  - Have to judge the reliability
- Tag the relations by 'quality indicators'
  - Some parameters that are relevant as a probability estimation
  - Location:
    - Accuracy: standard error
    - Freshness: timestamp and lifetime associated



# Conclusion

- Generic abstract concepts → implementation models → queried by apps
  - Show by case study
- Future work on privacy and distribution of context information