Sensing and Context-awareness

Sensing and context-awareness (1)

- The context of an entity is an aspect of its physical circumstances of relevance to system behaviour
  - Location, time, environmental conditions, associated users, what is nearby but also users' activities
- Sensors are combinations of hardware and software used to measure contextual values
  - Location (GPS), velocity (accelerometers) and orientation (magnetometers and gyroscopes)
  - Ambient conditions (thermometers, light sensors, sound sensors)
  - Presence (physical load detectors, RFID tags and readers, infrared readers)

Sensing and context-awareness (2)

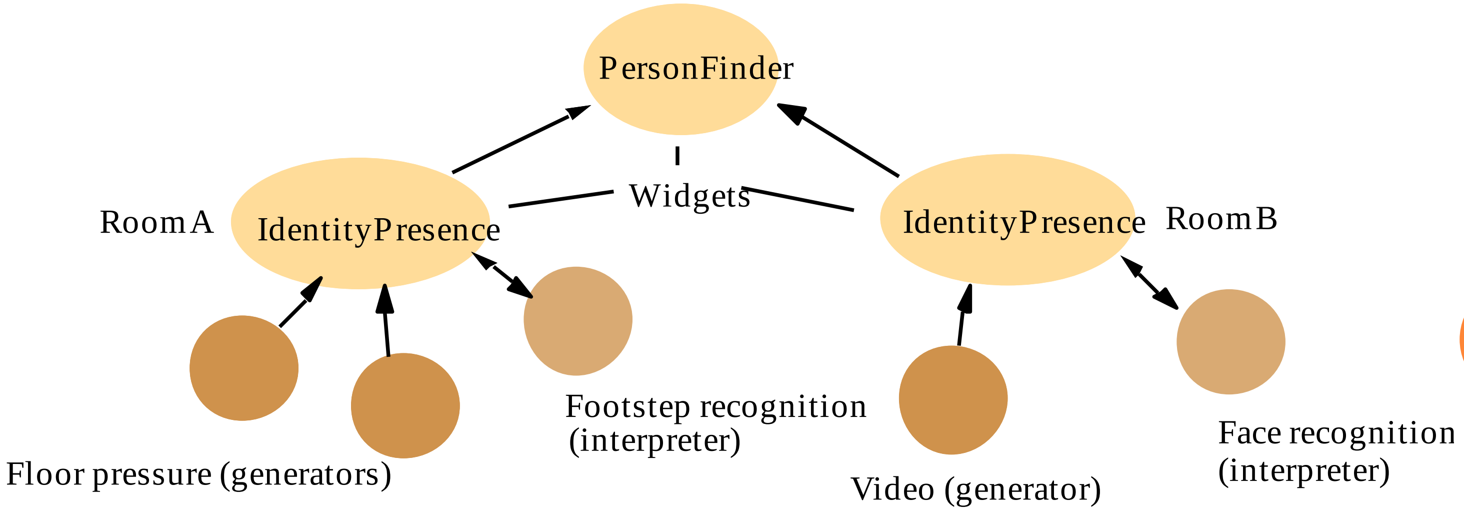
- Error model
  - Basic: well-known tolerance and with a known distribution
  - More complex: inability to produce measurement, dynamic factors (occlusions, ionospheric conditions), best-effort estimate, spurious readings
- Accuracy for a specified proportion of measurements
- Confidence (0-1) – according to measurement uncertainties

Sensing architectures (1)

- The challenges
  - Integration of idiosyncratic sensors
    - Unusual construction and programming interface
    - Deployment requires specialised knowledge
    - Potential lack of device drivers
  - Abstracting from sensor data
    - Sensors for similar purposes providing different raw data
    - Need for agreement on contextual attribute meaning and software to infer them from raw sensor data
  - Sensor outputs may need to be combined
    - Sensor fusion – improving sensing reliability/reducing errors through sensor combination
    - Application may require multiple contextual attributes
  - Context is dynamic
    - React to changes in context

SENSING ARCHITECTURES (2)

- Sensing in the infrastructure
  - Active badges – context-triggered actions
  - Context toolkit: context widgets (generators, interpreters, servers) – polling and callbacks
    - Accommodates a variety of sensor types, produces abstract contextual attributes, supports applications notification of context changes
    - Does not help in the integration of idiosyncratic sensors, does not solve the hard problems of sensor interpretation and combination for specific cases



Sensing architectures (3)

- Wireless sensor networks
  - Consists of a typically large number of small, low-cost devices or nodes, each with facilities for sensing, computing and wireless communication
    - Special case of ad-hoc networks – randomly arranged nodes communicating over multiple wireless hops
      - ZigBee (IEEE 802.15.4)
    - Design goal: function without any global control
  - Added to an existing environment to function independently
    - Deployment at a sufficient node density for full connectivity and significant phenomena sensing

SENSING ARCHITECTURES (4)

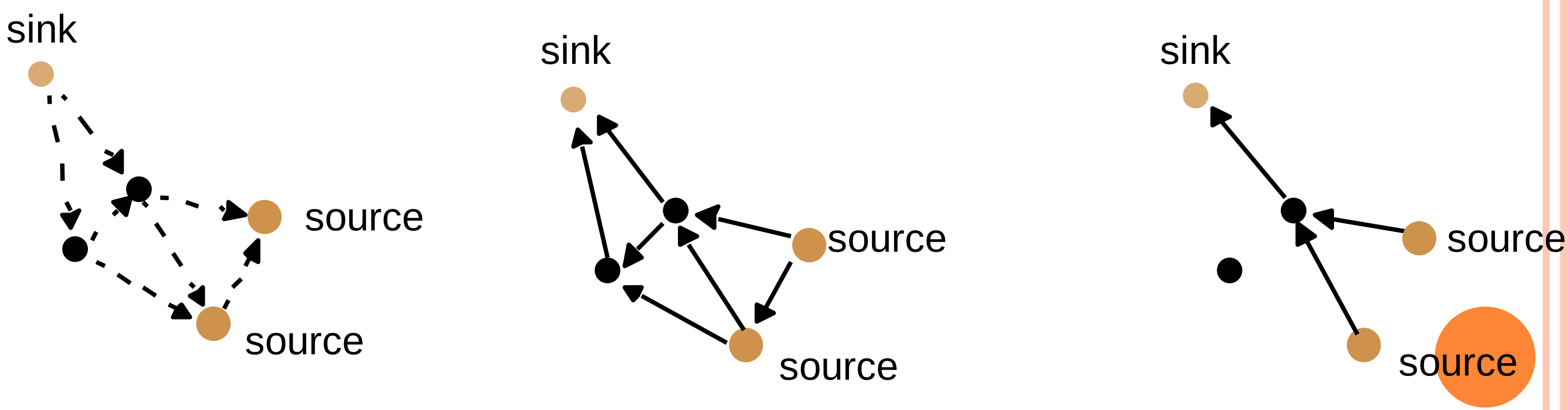
- Highly volatile
  - Battery exhaustion and accidents, node failure and affects in radio propagation
  - Mobile ad-hoc networks
- Application-specific purpose – detecting alarms that root node communicates them to a system that reacts to them
- Software architecture approaches
  - Separate network layer from higher layers: adaptive routing algorithms, but not necessarily tuned to low energy and bandwidth consumption, and volatility undermines the assumptions in the layers above
  - First principle approach: energy conservation and continuous operation despite volatility

Sensing architectures (5)

- Architectural features
  - In-network processing
    - 3 million instructions = transmit 1Kbit 100m by radio
    - Data aggregation, averaging, filtering, examination – control sensor operation
  - Disruption-tolerant networking
    - Questioning the end-to-end argument: no end-to-end path exists continuously for long enough to achieve some operations
    - Opportunistic communication and successive node responsibility
    - Bundles: application data and processing and management information
    - Redundancy in forwarding to guard against failure
    - Techniques also applicable to interplanetary networks

Sensing architectures (6)

- Data-oriented programming models
  - Directed diffusion: interests injected into sinks, interest propagation with diffusion until source is found (considerable redundant communication, but localisation of interests), flow of data from source to sink controlled by gradients (direction, value (control flow rate)), filter on nodes for flows – choosing among multiple paths



A. Interest propagation B. Gradients set up C. Data delivery

Sensing architectures (7)

- Distributed query processing: SQL-like queries with an optimised plan for execution devised at a base station, distribution of optimised queries along dynamically discovered routes possibly with in network processing, results flow back to base station
- Distributing processing across nodes and eliminating node and component identities

Location-sensing (1)

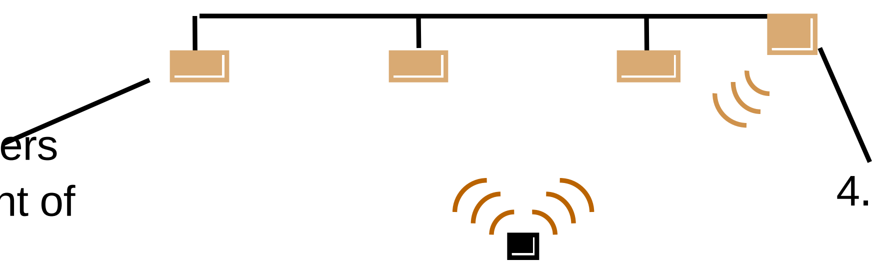
- Applications: location as central part of context, navigation assistance, determination of network routes by geography
- Who determines the location?
  - Tracking has privacy implications
- Satellite positioning: GPS, GLONASS, Galileo
  - GPS: 24 satellites orbiting earth in 6 planes twice per day – time of signal arrival and multilateration, requires 3 visible satellites for latitude and longitude more for altitude

Location-sensing (2)

Type	*Mechanism*	*Limitations*	*Accuracy*	*Type of location data*	*Privacy*
GPS	Multilateration from satellite radio sources	Outdoors only (satellite visibility)	1–10m	Absolute geographic coordinates (latitude, longitude, altitude)	Yes
Radio beaconing	Broadcasts from wireless base stations (GSM, 802.11, Bluetooth)	Areas with wireless coverage	10m–1km	Proximity to known entity (usually semantic)	Yes
Active Bat	Multilateration from radio and ultrasound	Ceiling mounted sensors	10cm	Relative (room) coordinates.	Bat identity disclosed
Ultra Wide Band	Multilateration from reception of radio pulses	Receiver in stallations	15cm	Relative (room) coordinates	Tag identity disclosed
Active badge	Infrared sensing	Sunlight or fluorescent light	Room size	Proximity to known entity (usually semantic)	Badge identity disclosed
Automatic identification tag	RFID, Near Field Communication, visual tag (e.g. barcode)	Reader installations	1cm–10m	Proximity to known entity (usually semantic)	Tag identity disclosed
Easy Living	Vision, triangulation	Camera installations	Variable	Relative (room) coordinates	No

Location-sensing (3)

- Proximity determination through base station signal strength calculation – absolute position require database with location of base stations
  - Triggering when in proximity of a particular location, finding things near by (e.g. Bluetooth)
- Absolute versus relative location
- Ultra sound, Ultra wide band (through walls and low energy consumption)



Location-sensing (4)

- Physical location: coordinates in a physical region
  - GIS and world models
- Semantic location: the location's name or description
- Automatic identification tags
  - Active badges, RFID tags, Near Field Communication, glyphs and barcodes
  - Identifiers may provide additional information
- Cameras and vision algorithms
- Privacy considerations
  - Absolute privacy (e.g. GPS)
  - Tracking no privacy even if identity is not disclosed

Location-sensing (5)

- Architectures for location-sensing
  - Key characteristics
    - Generality with respect to sensor types used
    - Scalability with respect to number of objects location and rate of location update events
  - Location stack: sensor layer, measurement layer, fusion layer (probabilistic inferencing), arrangements layer, additional layers for more complex contextual attributes
  - Spatio-temporal queries – scalability through region division
    - Indexing of spatial and temporal databases

Sensing and context-awareness

- Key problem: systems are still very crude compared to human understanding of the environment
  - Producing semantically rich information accurately from sensor data is extremely difficult
  - Robotics have achieved some progress in restricted domains but generalisation remain elusive