Internet of Things
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Life Cycles and Application Domains

Johan Lukkien
Tanir Ozcelebi
Leila Rahmann

John Carpenter, 1982
Questions

- What is the life cycle of IoT systems and components?
- What is the impact of the application domain on these life cycles?

- domains
  - home
  - mobile / outdoor (fields, ad-hoc)
  - office
  - industry
  - public (city)

- architecture, layered and deployment view
  - devices, things
  - functionality placement alternatives
  - data and control flow

- communication stack, protocols

- lifecycles
  - devices
  - services
  - applications
Life cycle

- The life cycle of a product or system is the series of stages it goes through from inception to decline.

- A typical life cycle for a software system is given to the right.

- More detail is obtained by adding information regarding the activities in the stages.

- Notes:
  - also system parts have life cycles, affecting the overall system.
  - the life cycle also addresses evolution, redesign.

Johan J. Lukkien, j.j.lukkien@tue.nl
TU/e Informatica, System Architecture and Networking
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Life cycles for IoT

- IoT life cycles pertain to
  - devices
  - (software) components & services
  - applications

- IoT applications are networked
  - distributed system (distributed programming)
    • needs concept development and tooling support
  - cumbersome deployment & commissioning
  - inevitably, increasing points of failure
    • require machine intelligence both in deployment as well in self management during the life cycle

- Concrete life cycles differ per domain
  - Home
  - Office
  - Outdoor
    • city
    • field – e.g. crops
    • mobile – vehicles, people
    • ad-hoc (emergency response)
  - Industry

- Life cycle stages have typical use cases and actors (stakeholders) in those cases
- Life cycle analysis is key in understanding architectural requirements
IoT Device life cycle

- Life cycles have a generic structure but are different for each device type
- Examples:
  - **phone**: deployment is through purchasing; other commissioning is through manufacturer. Life cycle server is with connectivity provider or manufacturer; operation is by user
  - **office IoT**: commissioning is by an installation company. Life cycle server is with owner or with manufacturer.
- Important aspects concern responsibilities and control by involved stakeholders
  - in particular: responsibility for software updates
Example: commissioning of mediaplayer

- Mediaplayer device contains separate access point
- Mediaplayer may be difficult to reach (for updates)
- MP-AP must be as secure as the home network
- Malicious takeover of MP difficult to see
IoT: involved software types

- Embedded Operating System / runtime executive, middleware
  - typically installed as part of a firmware image
  - supporting the running of components, applications
- Libraries
  - e.g. a CoAP library, linked into an executable
- (Runnable) components exposing services
  - e.g. a CoAP based service for inspecting the temperature or adjusting the heater
- Applications (application components)
  - e.g. a management application using temperature services and controlling the heater
  - e.g. a data analytics application
IoT: software update packaging

- Firmware
  - full update of a node’s software
- Module
  - a library or application component, possibly even an OS or system part
- Setting
  - parameter settings on the existing system
IoT service and component life cycle

- Components deliver services, or take part in that
- Example:
  - **temperature service**: a component implementing a temperature service is installed on the sensor node over the air
- Recommissioning is triggered by renewal of libraries, of versions
- Important again are **responsibilities and control** by involved stakeholders
  - in particular: responsibility for software updates after first install
  - also of commissioning, service publication (repository)
IoT Application life cycle

- Life cycles of applications may depend on life cycles of components, libraries
- Examples:
  - thermostat application: searches and finds services that yield temperature and control services that control the heater (needs further details and access control of course)
- Important aspects concern access control by involved stakeholders
Extra functional properties: dependability throughout the life cycle

- **Security**
  - network must trust new device
  - execution platform must trust new components
  - access control, authentication, authorization
  - encryption, certification
  - security (key, access) management

- **Privacy**
  - control about personal information
  - retain information within context
  - information modeling, aggregation
  - components must obey privacy rules

- **Reliability, availability, safety**
  - self monitoring and repair of broken updates
Characteristics of the home domain

- The home is in principle unmanaged
  - one-time configuration of new equipment
    - legacy effects: a very old device requiring obsolete security protocols
    - default configuration not altered
    - wide variety of policies and mechanisms for installation
  - responsibility for software updates not assigned
    - devices difficult to reach after installation
    - automatic update by manufacturer is a security and functionality hazard
  - problems and side effects very difficult to understand
    - lack of conceptual model
    - lack of management addressing system level concerns like data protection and service quality
    - no control over data
  - no money available for extra management services
The office domain

• The office is managed
  – central access control, policies
  – clear procedures and responsibilities for system updates
  – extensive standardization is possible
  – higher cost acceptable

• Conflicting concerns of stakeholders
  – ‘BYOD’ interferes
  – Data management
    • office manager has details about users, visitors
Other domains have further characteristics

- City, mobile:
  - services provide access to infrastructure
  - ownership needs attention
- Industry
  - single owner of data
  - very controlled environment
  - production data integrated with process improvement, maintenance and logistics

- These characteristics:
  - alter the implementation of the life cycles
  - lead to very different problems in life cycle stages
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