Semantic Gadgets - Extending the Semantic Web to Physical Devices

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Internet & Mobility: a Future

Mobility Makes Things Different

- **Device location is a completely new dimension**
  - more information about the user and the usage context available
  - new applications & services are possible
- **Devices are different**
  - reduced capabilities: smaller screens, slow input devices, lower bandwidth, higher latency, worse reliability, …
  - trusted device: always with you & has access to your private data
- **Usage contexts and needs are different**
  - awkward usage situations (e.g., in the car while driving)
  - specific needs (“surfing” unlikely)
  - you are always “on” (= connected)
- **Dilemma:**
  - the Internet represents a departure from physical reality
    BUT mobility grounds services & users to the physical world

Critical Components of Mobile Internet

- **Access to internet-based services from small handheld terminals**
  - first step: WAP (quick build-up of a large user base)
  - initial applications include personal information management and connectivity, “infotainment”, (mobile) e-commerce, vertical applications & access to corporate intranet data
- **Dynamic synthesis of content**
  - first step: data in XML, transformations to suitable formats
  - device independence is key to long term interoperability
- **Context-dependence**
  - first step: customization and personalization
  - adaptation of services based on context
  - location is one dimension of a “context”, but there are others

New Enabling Technologies

- **Artificial Intelligence**
  - machine learning: allows us to customize, personalize and adapt without bothering the user
  - automated planning: enables autonomous operation (i.e., departure from the “tool metaphor” to delegation of decision-making power)
- **“Semantic Web”**
  - intelligent synthesis of personalized, context-dependent content from multiple information sources (ad hoc & on demand)
  - explicit representation of semantics of data & services
- **Ubiquitous Computing**
  - (a paradigm shift in personal computing)
  - LP RF networks, ad hoc networking, discovery of devices & services, etc.

“Semantic Web”

Semantic Web: Motivation & Features

- **Current WWW was built for humans, not for machines**
- **"Semantic Web" is like a global KB**
  - (cf. use of the WWW as an infrastructure)
  - better security & privacy will allow us to reason about trust, enabling completely new kinds of services and businesses
  - content-with-semantics paves way for the use of software agents
- **Hyperlinks with meaning**
  - agents can navigate the WWW by following semantic links
- **What will happen when data comes with semantics?**
  - data from different sources can be combined
    - new, perhaps unforeseen opportunities and functionality will result
  - machines can meaningfully use the WWW and perform tasks on our behalf ("machine-understandable" content)

Resource Description Framework

- **RDF is a data model**
  - the model is domain-neutral, application-neutral and ready for internationalization (i18n)
  - the model can be viewed as directed, labeled graphs or as an object-oriented model (object/attribute/value)
  - can describe anything that has a URI
  - the specification provides an encoding (in XML) of the model
  - important: syntactic details are secondary, they are largely handled by using XML (RDF defines a convention of XML usage)
- **RDF data model is a conceptual layer on top of XML**
  - consequently, RDF is independent of XML
  - RDF data might not be stored in XML form
    - it might reside, for example, in an RDB
  - XML relieves us of syntactic details when transporting RDF

DARPA Agent Markup Language

- **DAML is a research program that develops technologies for the Semantic Web**
  - DARPA program
  - broader effort (including EU)
- **Adds logic layers on top of RDF**
- **Builds basic ontologies**

Ubiquitous Computing

What is Ubiquitous Computing?

- **Term originally coined by Mark Weiser (Xerox PARC)**
  - a.k.a. “pervasive computing”, “calm computing”
- **Proliferation of computing capabilities into everyday objects (appliances etc.)**
- **User interaction with the environment**
  - (as opposed to interaction with some specific device)
  - pushing many tasks into the periphery of users’ attention

Ubiquitous Computing @ NRC/AT

- **Observing some general trends**
  - + handheld computing devices
  - + wireless communication
  - + internet connects “everything”
  - - but, technology is not necessarily becoming easier to use
- **Smart rooms: earlier focus on “static” configurations**
  - how people really live and work has largely been ignored
  - functions: context identification, remote control
- **Our goal: “things should just work”**
  - devices should automatically “figure out what to do”, form communities and collaborate
  - environment should adapt to users, not vice versa
  - environments are “dynamic”: changes should cause minimal disruption

Ubiquitous Computing @ NRC/AT

- **Our current collaboration**
  - MIT LCS (Oxygen & W3C)
  - UNH Constraint Computation Center
  - CMU Robotics Institute
  - DARPA
- **Related Projects**
  - Smart Environment
    - develops a “smart room” starting from the idea that devices should form “smart communities” on an ad hoc basis
  - Ad Hoc Self-Organizing Networks (“AH-SO!”)
    - pursues lower level issues in ad hoc networking
    - prerequisite for the smart environment

Low-level Discovery Services

- **Large number of discovery/name/directory services**
  - file systems
  - DHCP, DNS
  - SLP, LDAP, X.500
  - crawlers, web search engines
- **Each service uses different**
  - metadata
  - protocols
  - query language
- **Disadvantages of this include**
  - proliferation of different tools and APIs
  - incomplete & inconsistent views of the same data
  - network management complications due to the above

NRC/AT “AH-SO!” Discovery

- Discovery protocols are separated from query language and metadata
- Single metadata language and toolkit (RDF)
- Low-level query language that can handle native RDF data model queries
- Prototype implementation based on SLP

Role of Standardization

- **Open standards are a prerequisite for interoperability**
- **Many initiatives for device, service & capability discovery**
  - UPnP (Microsoft et al), JINI (Sun), Salutation (several companies), …
  - Service Location Protocol SLP (IETF)
  - CC/PP (W3C)
- **But, standards will "only get us so far"**
  - beyond, we need "reasoning"
  - many emerging standards are in trouble because of vocabularies
    - CC/PP, P3P (adoption hindered by lack of vocabularies)
    - proliferation of (specialized) XML DTDs
    - Dublin Core (4 years, 15 attributes!)
    - lack of tools for maintaining (e.g., merging) vocabularies

“Semantic Gadgets”

What Are Semantic Gadgets?

- **Combine ubiquitous computing & the Semantic Web**
  - devices capabilities and service functionality explicitly represented
  - everything is addressable (using URIs)
  - Semantic Web is the basis for “semantic interoperability”
- **Critical components**
  - connectivity
    - wireless, ad hoc networks + service discovery
  - representation
    - models of devices, services, users, environments, etc.
  - reasoning
    - learning
    - planning
- **Other useful technologies**
  - sensors, context-awareness, mobile code, …

Smart Communities of Devices

- **All devices advertise their services**
- **A device can extend its functionality by**
  - discovering missing functionality offered by another device
  - contracting the use of the service
- **Everything can be discovered**
  - including “reasoning services” or who is going to develop overall plans for integrating devices into larger, task-oriented “teams”
  - (OK, we are still working on this…)

NRC/AT Prototype Architecture (1999)

- **Agent-based approach to “smart environments”**
  - agents represent devices, users, and the room
  - discovery and exchange of capabilities, goals, etc.
  - RDF metadata as the basic representational framework
- **Simple architecture with the following components:**
  - sensory agents
    - represent devices which accept user input (speech, gestures, etc.)
  - manipulation agents
    - represent devices which are capable of causing physical actions such as dimming lights, closing shades, projecting slides, etc.
  - problem solving agents
    - input “fusion”, goal formation
    - planning
    - action delegation to manipulation agents

NRC/AT Prototype Architecture (1999)

- **Ad hoc connectivity**
  - (current implementation uses a fixed network w/ X10 for physical control)
  - designed to use a wireless, ad hoc network
- **Layered architecture**

<table>
<tr><td colspan="2">“gadgets”</td></tr>
<tr><td>multi-agent framework</td><td>RDF++ (representation)</td></tr>
<tr><td colspan="2">ad hoc (i.e., self-configuring) network</td></tr>
<tr><td colspan="2">wireless bearer (e.g., IEEE 802.11 or Bluetooth)</td></tr>
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Future Work

- **Bridging the gap between low-level discovery and high-level advertising & querying**
  - e.g., develop a “UPnP Ontology” for DAML
  - proxy architecture for translation
    - devices can volunteer to translate (and can be discovered)
- **“Semantic Napster”**
  - peer-to-peer sharing of semantic information
- **Other stuff…**
  - for smart environments, we also need something like common sense reasoning (naïve physics?)

Questions?

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