Semantic Gadgets - Extending the Semantic Web to Physical Devices

Ora Lassila

Research Fellow
Agent Technology Group, Nokia Research Center

November 2000
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>
<thead>
<tr>
<th>“gadgets”</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>multi-agent framework</td>
<td>RDF++ (representation)</td>
</tr>
<tr>
<td>ad hoc (i.e., self-configuring) network</td>
<td></td>
</tr>
<tr>
<td>wireless bearer (e.g., IEEE 802.11 or Bluetooth)</td>
<td></td>
</tr>
</tbody>
</table>
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?

- mailto:ora.lassila@nokia.com