Context Awareness and Service Discovery for Spontaneous Networking

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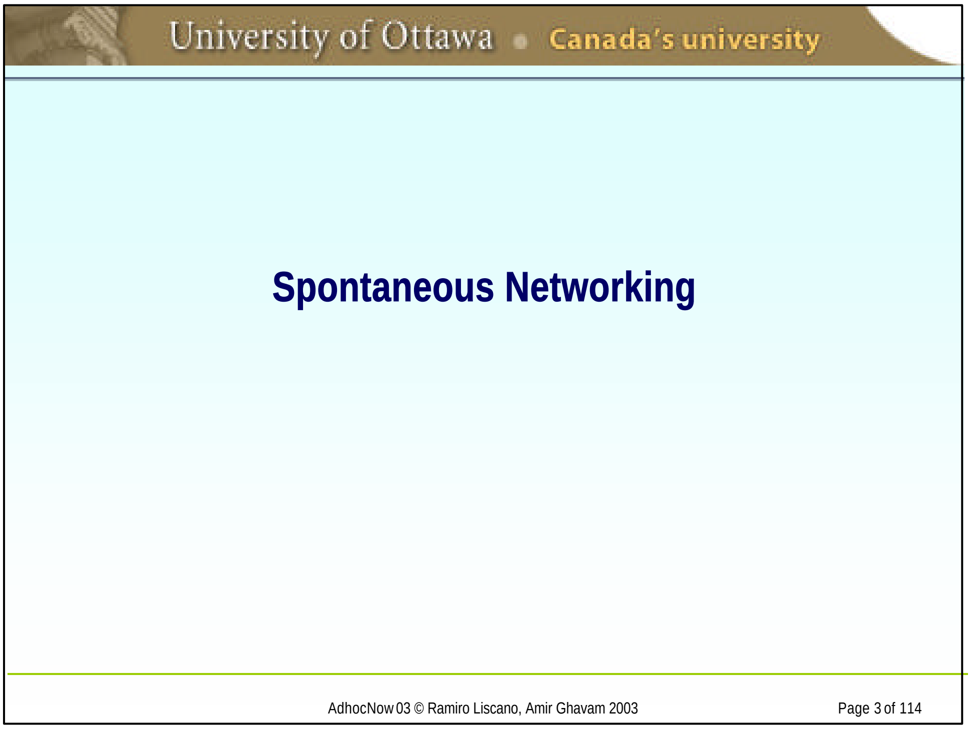
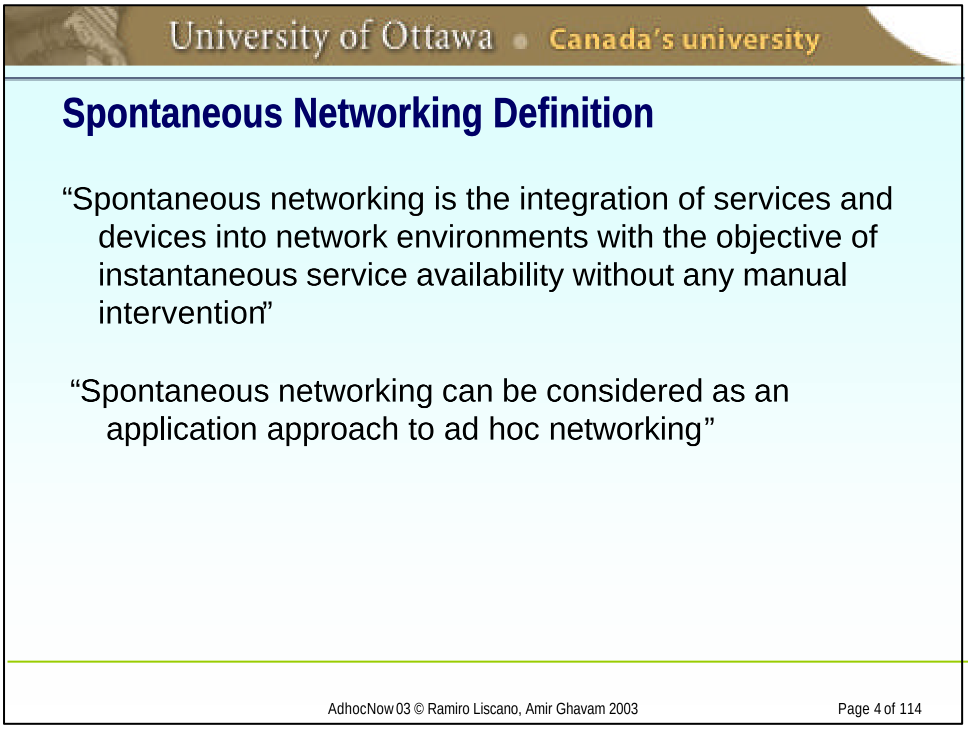
Tutorial Overview

- What is Spontaneous Networking?
- Service Discovery Protocols
  - Basics
  - Protocols BT SDP & IETF SLP
- Context-Aware Service Discovery
  - Value of Context
  - Context Awareness
  - Frameworks
  - Examples of Context-Enhanced S.D.
- Semantic Service Languages
  - Resource Description Framework (RDF)
  - Examples of RDF in Spontaneous Networking
  - Example of Semantic Ad hoc Interaction
- Summary



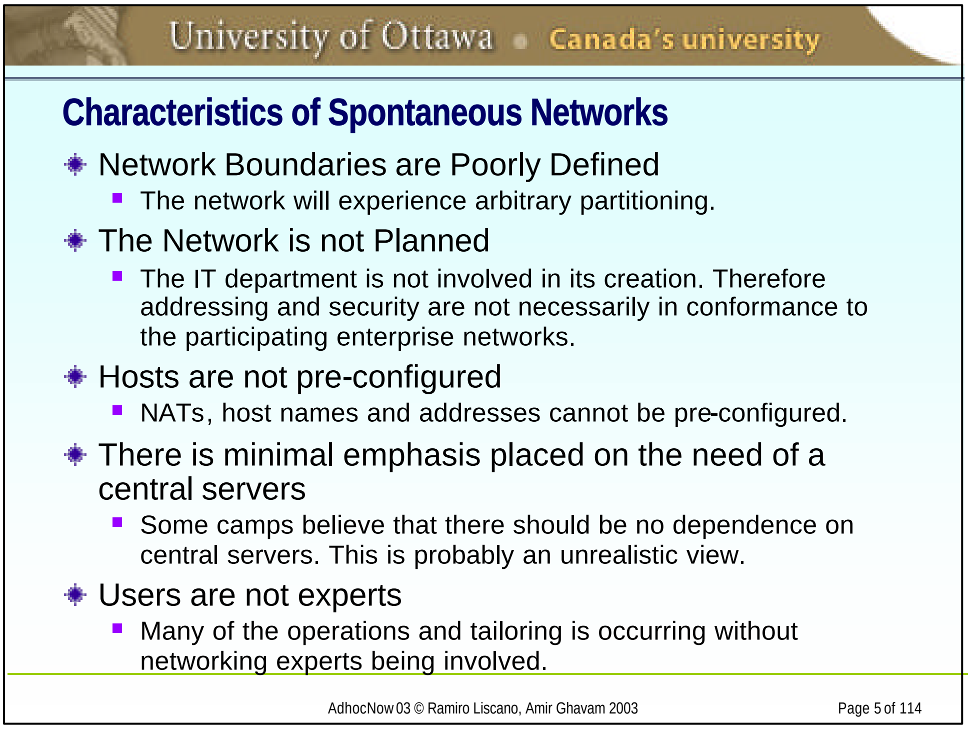
Spontaneous Networking



Spontaneous Networking Definition

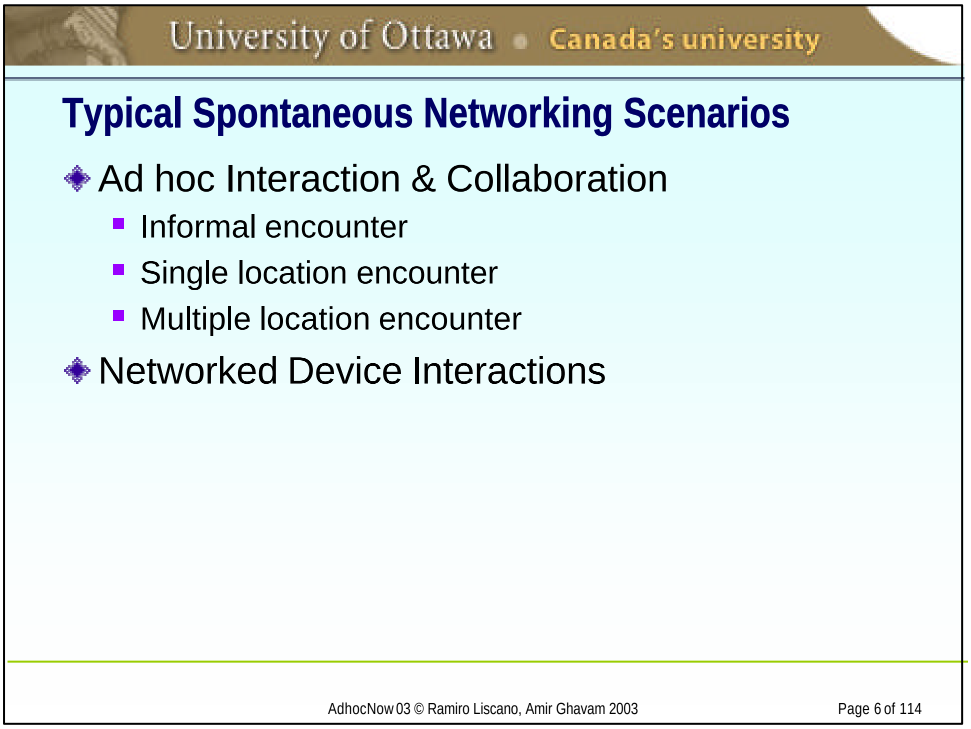
"Spontaneous networking is the integration of services and devices into network environments with the objective of instantaneous service availability without any manual intervention"

"Spontaneous networking can be considered as an application approach to ad hoc networking"



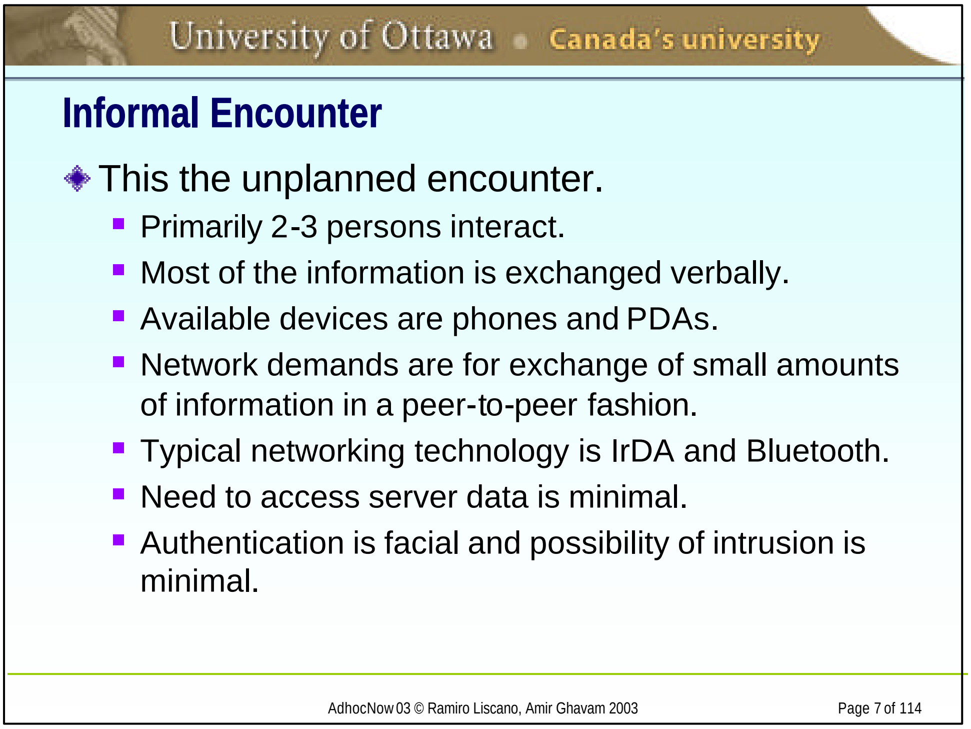
Characteristics of Spontaneous Networks

- Network Boundaries are Poorly Defined
  - The network will experience arbitrary partitioning.
- The Network is not Planned
  - The IT department is not involved in its creation. Therefore addressing and security are not necessarily in conformance to the participating enterprise networks.
- Hosts are not pre-configured
  - NATs, host names and addresses cannot be pre-configured.
- There is minimal emphasis placed on the need of a central servers
  - Some camps believe that there should be no dependence on central servers. This is probably an unrealistic view.
- Users are not experts
  - Many of the operations and tailoring is occurring without networking experts being involved.



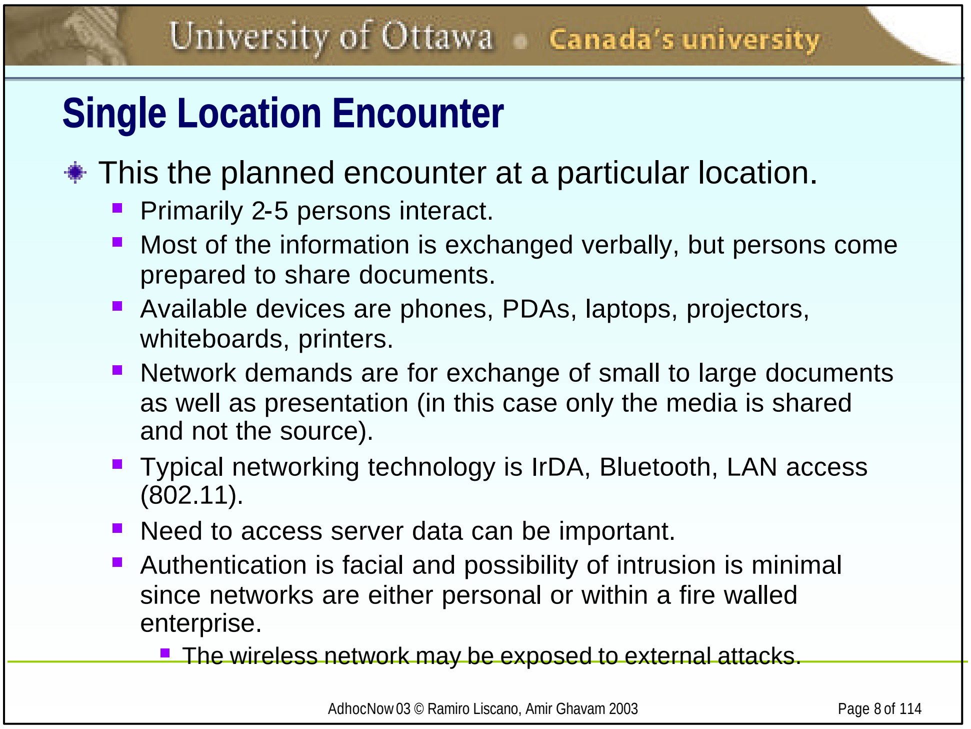
Typical Spontaneous Networking Scenarios

- Ad hoc Interaction & Collaboration
  - Informal encounter
  - Single location encounter
  - Multiple location encounter
- Networked Device Interactions



Informal Encounter

- This the unplanned encounter.
  - Primarily 2-3 persons interact.
  - Most of the information is exchanged verbally.
  - Available devices are phones and PDAs.
  - Network demands are for exchange of small amounts of information in a peer-to-peer fashion.
  - Typical networking technology is IrDA and Bluetooth.
  - Need to access server data is minimal.
  - Authentication is facial and possibility of intrusion is minimal.



Single Location Encounter

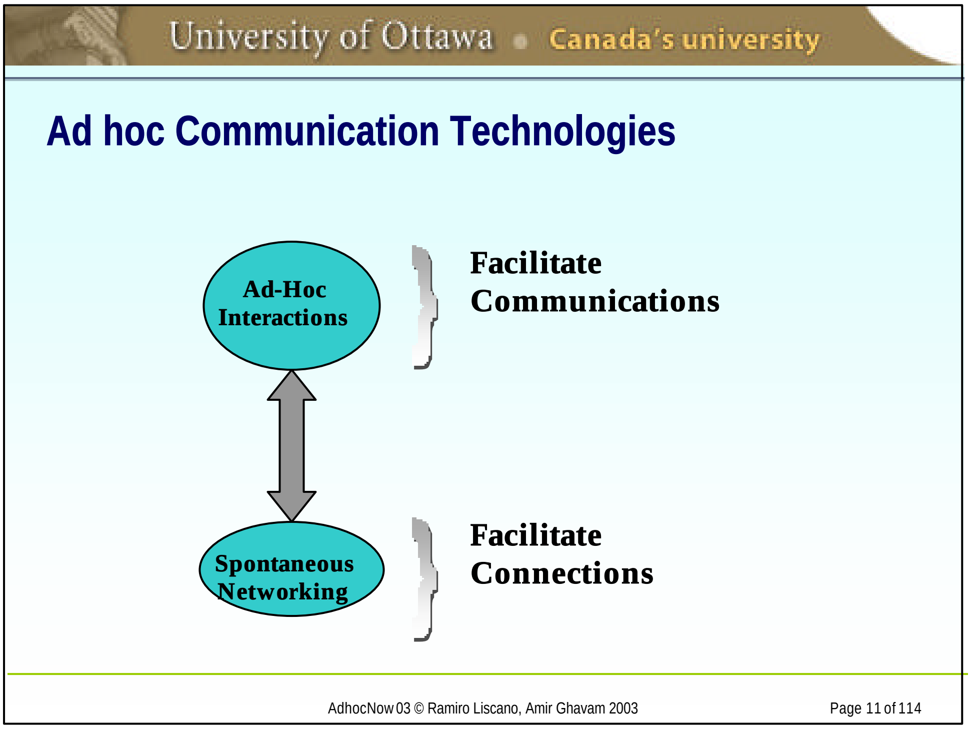
- This the planned encounter at a particular location.
  - Primarily 2-5 persons interact.
  - Most of the information is exchanged verbally, but persons come prepared to share documents.
  - Available devices are phones, PDAs, laptops, projectors, whiteboards, printers.
  - Network demands are for exchange of small to large documents as well as presentation (in this case only the media is shared and not the source).
  - Typical networking technology is IrDA, Bluetooth, LAN access (802.11).
  - Need to access server data can be important.
  - Authentication is facial and possibility of intrusion is minimal since networks are either personal or within a fire walled enterprise.
    - The wireless network may be exposed to external attacks.

Multiple Location Encounter

- This the planned encounter that takes place across physical locations.
  - The characteristics are the same as the single location meeting except for the following:
  - Network demands are extended to include anexisting LAN and WAN. Networks that are created in an ad hoc manner must interact with existing enterprise networks.
  - Global authentication of participants is difficult but a trust network is set up relying on the authentication of particular individuals at the end points.
  - Risk of intrusion is increased due to the use of public WAN.
  - Interaction with enterprise firewalls is inevitable,

Networked Device Interactions

- Generally a situation focused on the use of resources available in the vicinity of the user.
  - Generally it involves 1 person and several devices.
  - Available devices are phones, PDAs, laptops, projectors, whiteboards, printers.
  - Network demands are for the exchange of small to large amounts of information as well as streaming data in a peer-to-peer fashion.
  - Typical networking technology is IrDA and Bluetooth.
  - Need to access server data is non-existant.
  - Authentication is a minimal issue but ownership of devices is. Possibility of intrusion is minimal.



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Ad hoc Communication Technologies

Ad-Hoc Interactions

Facilitate Communications

Spontaneous Networking

Facilitate Connections

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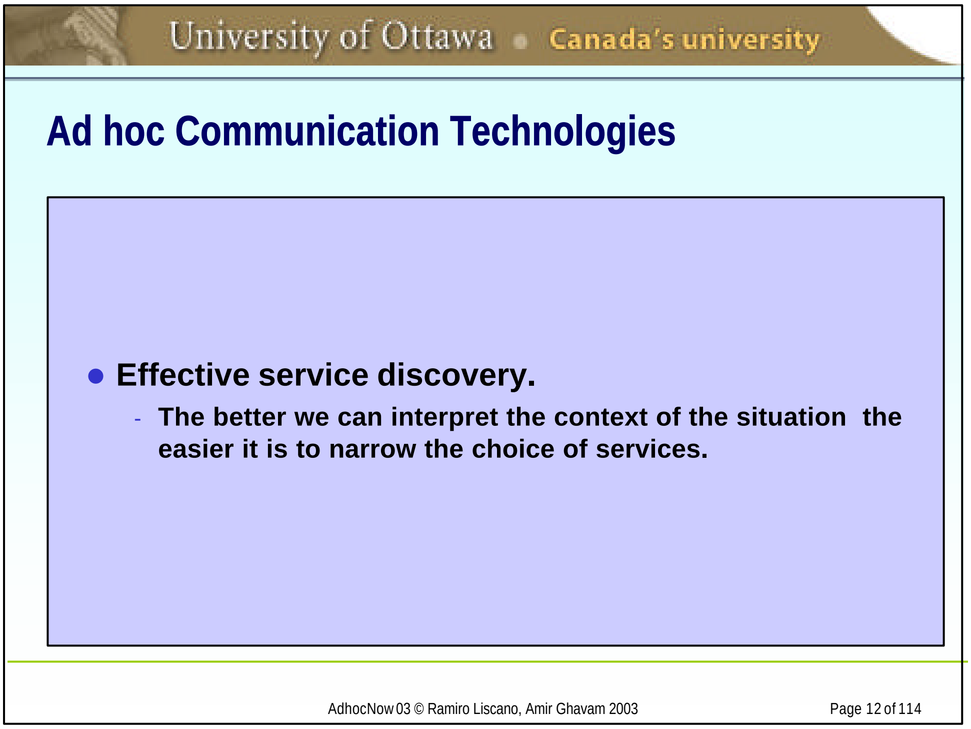

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Ad hoc Communication Technologies

- Effective service discovery.
  - The better we can interpret the context of the situation the easier it is to narrow the choice of services.

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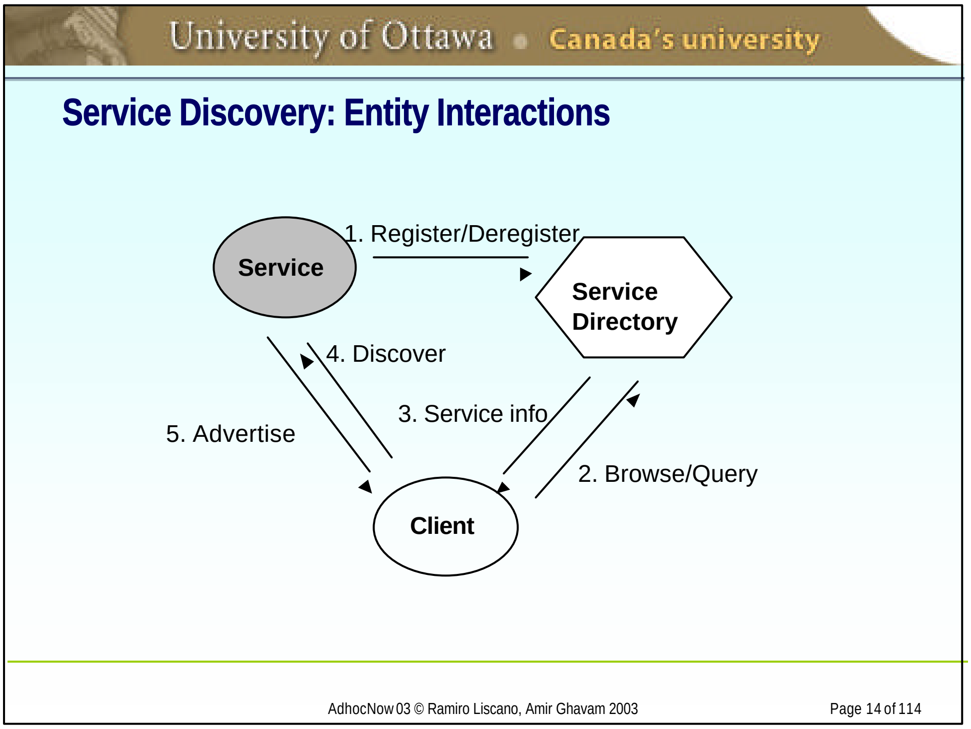
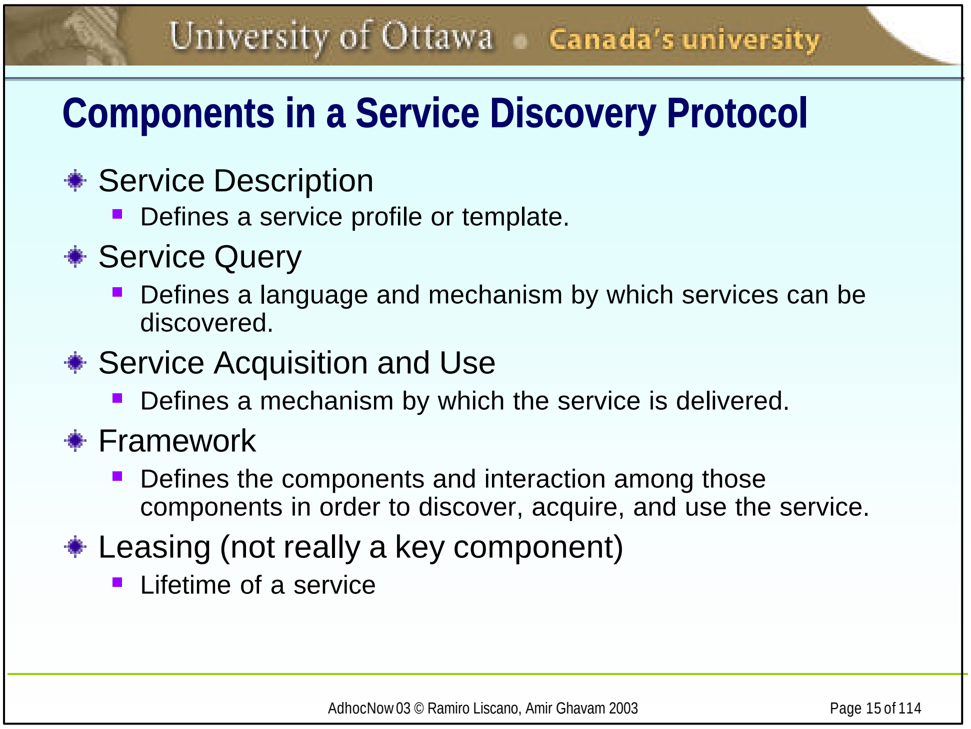
Service Discovery Protocols

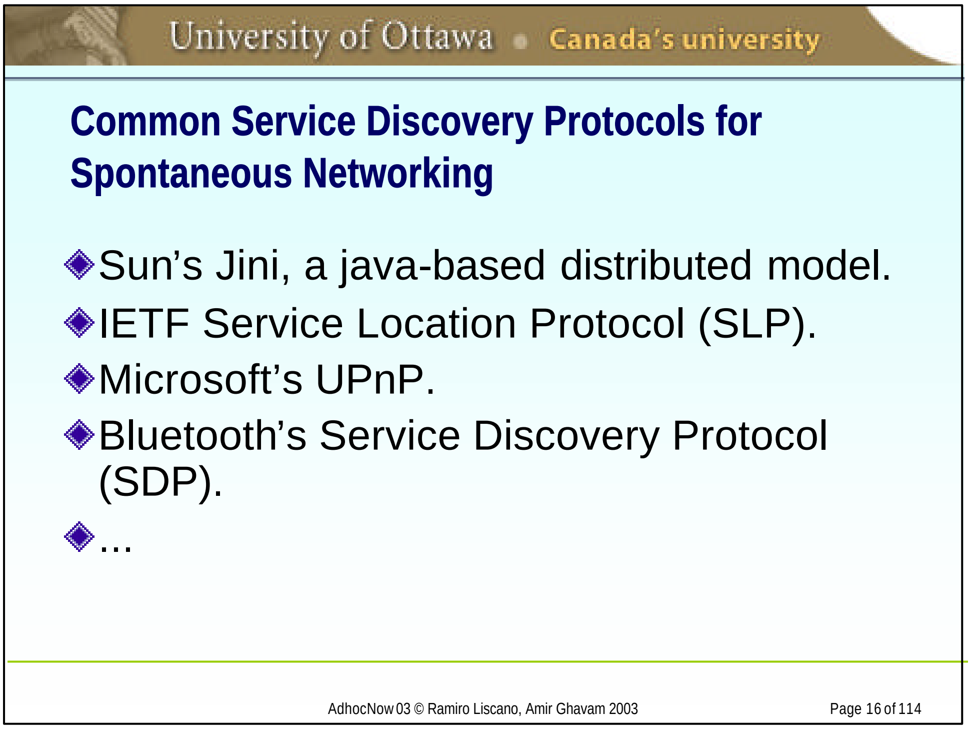


Service Discovery: Entity Interactions



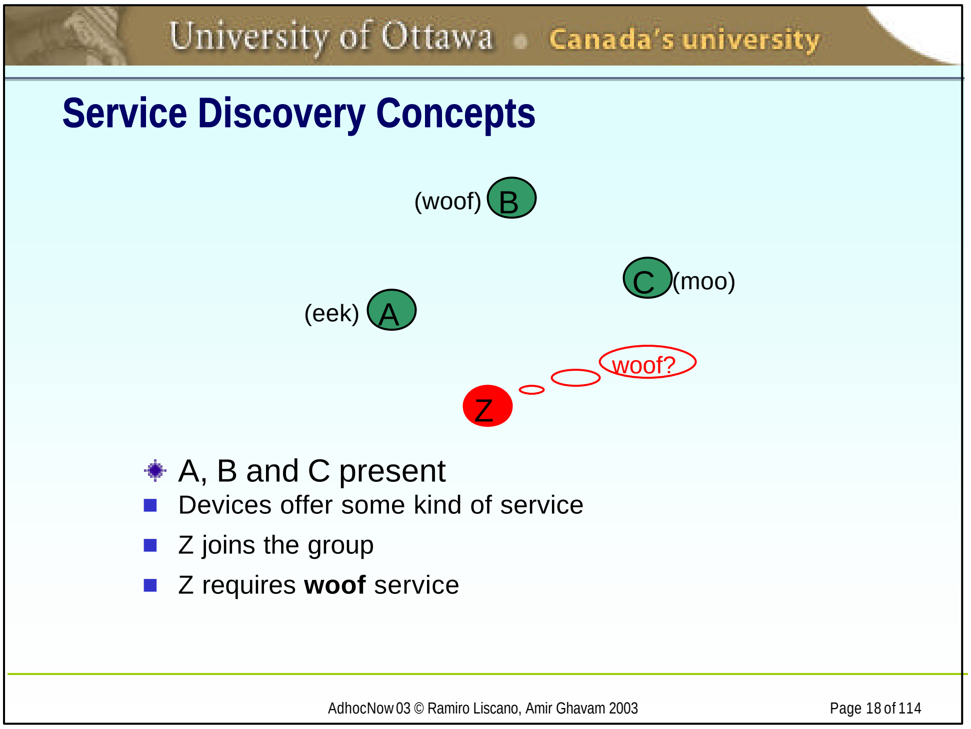
Components in a Service Discovery Protocol

- Service Description
  - Defines a service profile or template.
- Service Query
  - Defines a language and mechanism by which services can be discovered.
- Service Acquisition and Use
  - Defines a mechanism by which the service is delivered.
- Framework
  - Defines the components and interaction among those components in order to discover, acquire, and use the service.
- Leasing (not really a key component)
  - Lifetime of a service



Common Service Discovery Protocols for Spontaneous Networking

- Sun's Jini, a java-based distributed model.
- IETF Service Location Protocol (SLP).
- Microsoft's UPnP.
- Bluetooth's Service Discovery Protocol (SDP).
- ...



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Service Discovery Concepts

- A, B and C present
  - Devices offer some kind of service
  - Z joins the group
  - Z requires **woof** service

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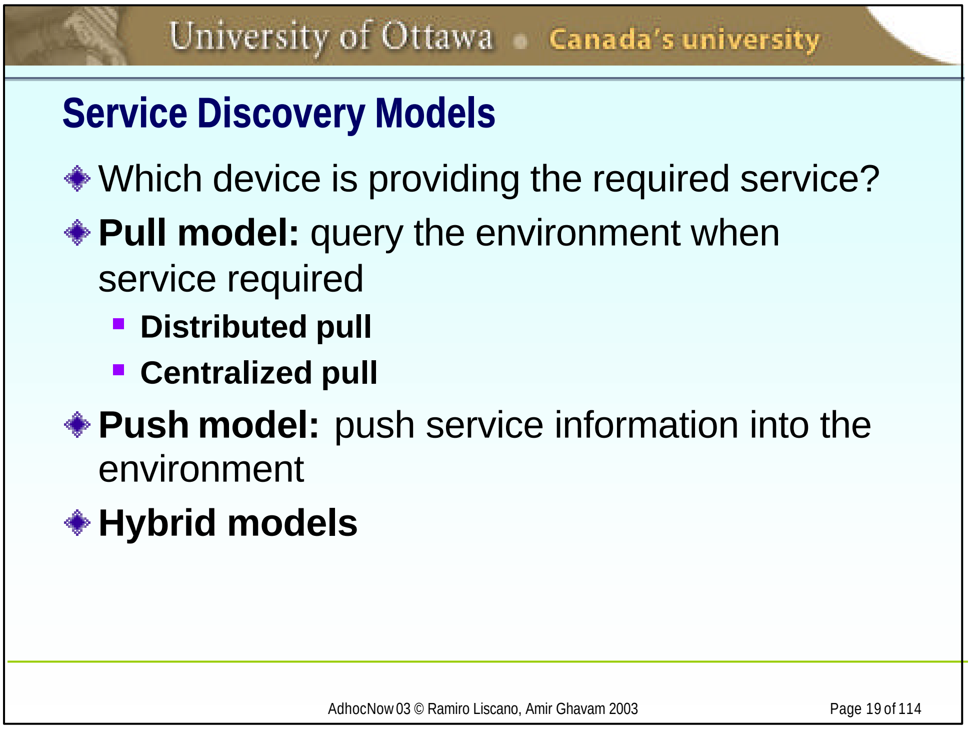

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Service Discovery Models

- Which device is providing the required service?
- **Pull model:** query the environment when service required
  - **Distributed pull**
  - **Centralized pull**
- **Push model:** push service information into the environment
- **Hybrid models**

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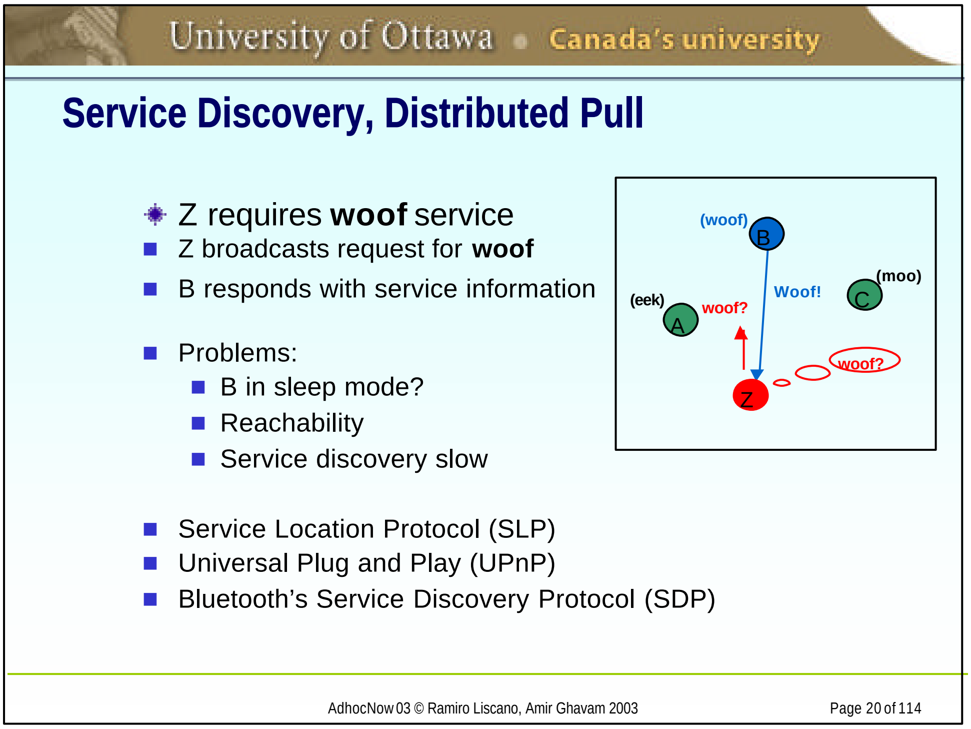
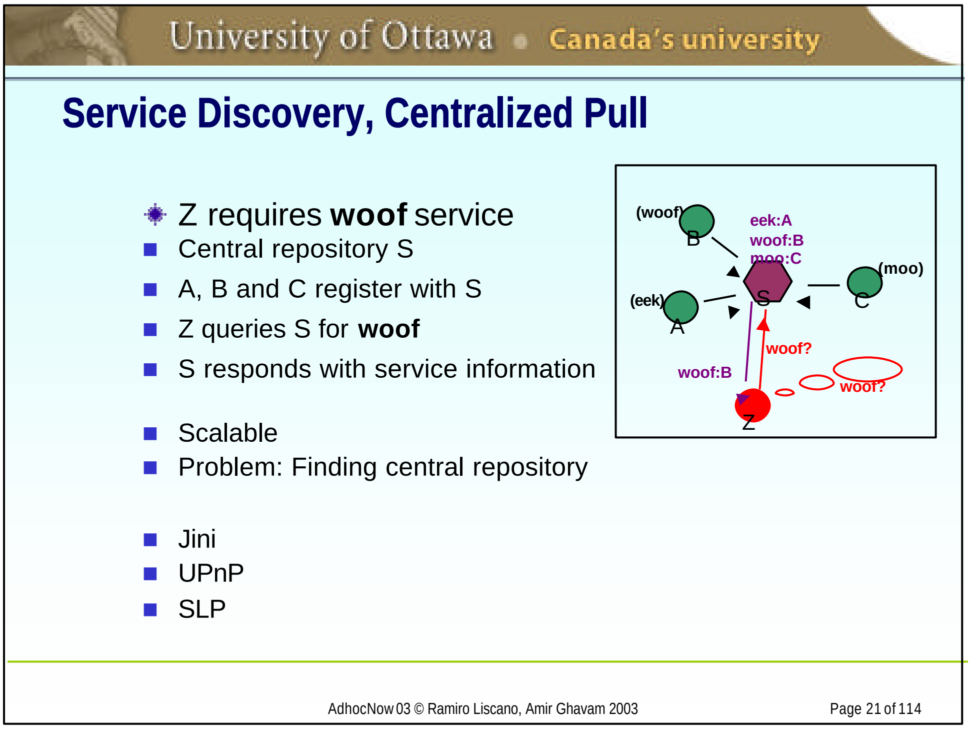


Service Discovery, Distributed Pull

- Z requires **woof** service
- Z broadcasts request for **woof**
- B responds with service information
- Problems:
  - B in sleep mode?
  - Reachability
  - Service discovery slow
- Service Location Protocol (SLP)
- Universal Plug and Play (UPnP)
- Bluetooth's Service Discovery Protocol (SDP)

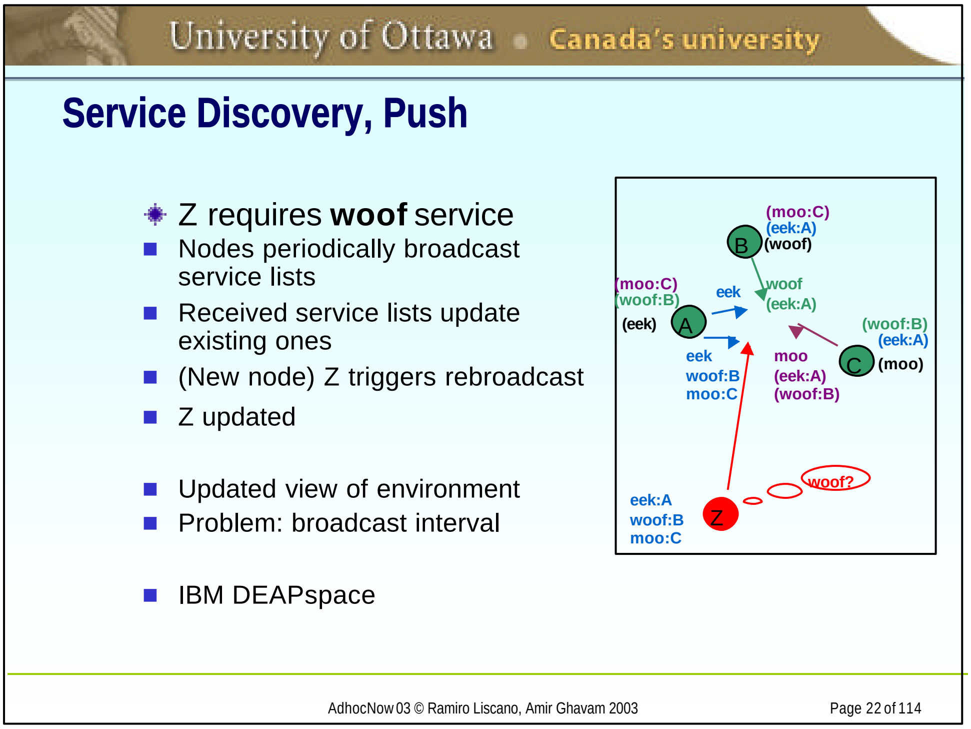
(woof)
B
(eek)
woof?
Woof!
C
(moo)
A
woof?
Z



Service Discovery, Centralized Pull

- Z requires **woof** service
- Central repository S
- A, B and C register with S
- Z queries S for **woof**
- S responds with service information
- Scalable
- Problem: Finding central repository
- Jini
- UPnP
- SLP

(woof)
B
eek:A
woof:B
moo:C
(moo)
(eek)
S
C
A
woof?
woof:B
woof?
Z



Service Discovery, Push

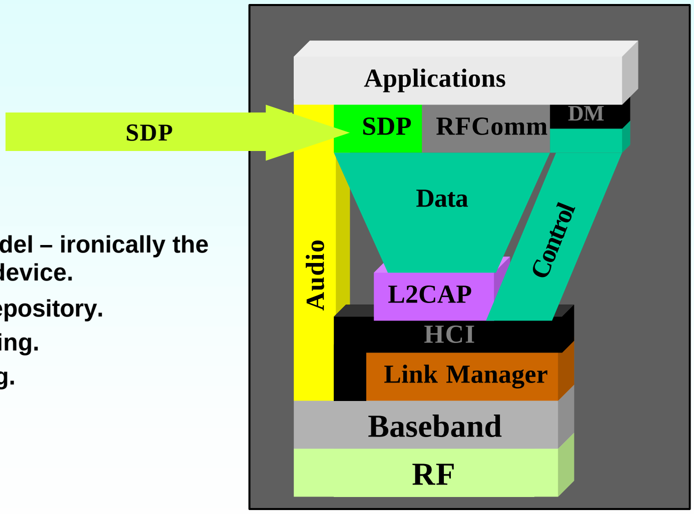
- Z requires **woof** service
- Nodes periodically broadcast service lists
- Received service lists update existing ones
- (New node) Z triggers rebroadcast
- Z updated

- Updated view of environment
- Problem: broadcast interval

- IBM DEAPspace

Bluetooth Service Discovery Protocol (SDP)

Service Discovery Protocol (SDP)



- Client server model – ironically the client is a Master device.
- Local Service Repository.
- Service advertising.
- Service browsing.

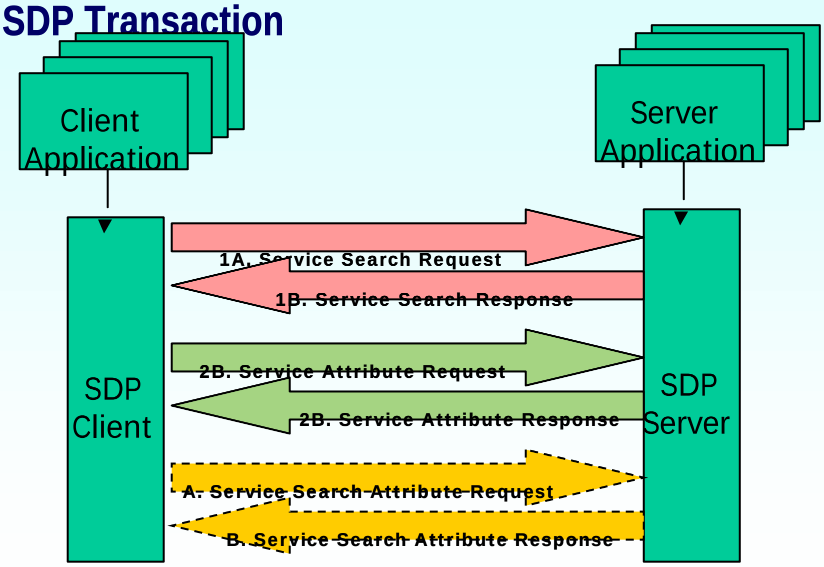
SDP Overview

- All devices must provide this capability, it is part of the specification
- Establish L2CAP connection to remote device
- Query for services
  - search for specific class of service, or
  - browse for services
- Retrieve attributes that detail how to connect to the service.
- Establish a separate (non-SDP) connection to use the service.

SDP Basics

- Universally Unique ID (UUID, from ISO) for identifying the class of each service
- Clients specify the UUID when looking for a service
- Idea: Using specific algorithms, UUID can be generated globally with the same value, no need for a central repository for service Ids
- Discovery is performed by exchanging SDP-Protocol Data Units (SDP_PDU)

SDP Transaction



Client Application

Server Application

SDP Client

SDP Server

1A. Service Search Request

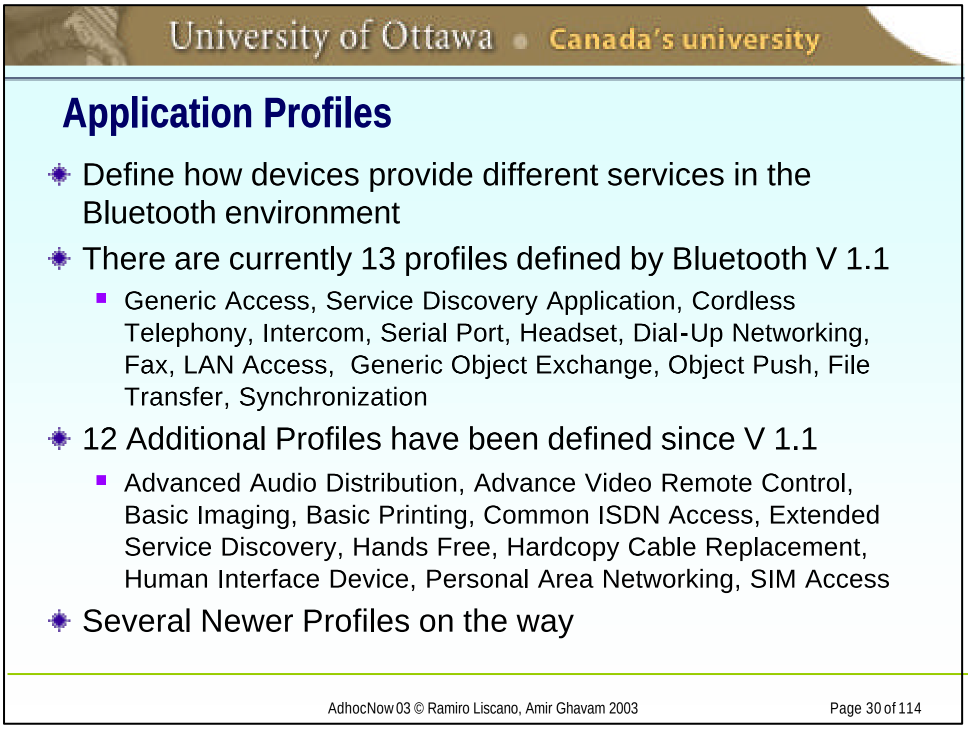
1B. Service Search Response

2B. Service Attribute Request

2B. Service Attribute Response

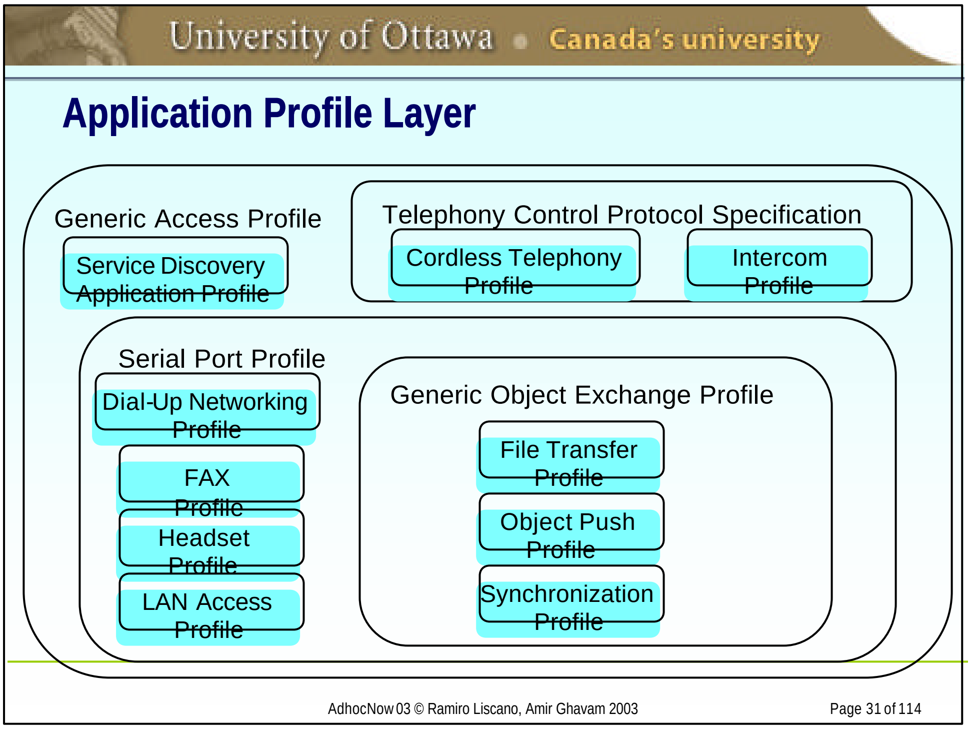
A. Service Search Attribute Request

B. Service Search Attribute Response



Application Profiles

- Define how devices provide different services in the Bluetooth environment
- There are currently 13 profiles defined by Bluetooth V 1.1
  - Generic Access, Service Discovery Application, Cordless Telephony, Intercom, Serial Port, Headset, Dial-Up Networking, Fax, LAN Access, Generic Object Exchange, Object Push, File Transfer, Synchronization
- 12 Additional Profiles have been defined since V 1.1
  - Advanced Audio Distribution, Advance Video Remote Control, Basic Imaging, Basic Printing, Common ISDN Access, Extended Service Discovery, Hands Free, Hardcopy Cable Replacement, Human Interface Device, Personal Area Networking, SIM Access
- Several Newer Profiles on the way



Application Profile Layer

Generic Access Profile

Service Discovery Application Profile

Telephony Control Protocol Specification

Cordless Telephony Profile

Intercom Profile

Serial Port Profile

Dial-Up Networking Profile

FAX Profile

Headset Profile

LAN Access Profile

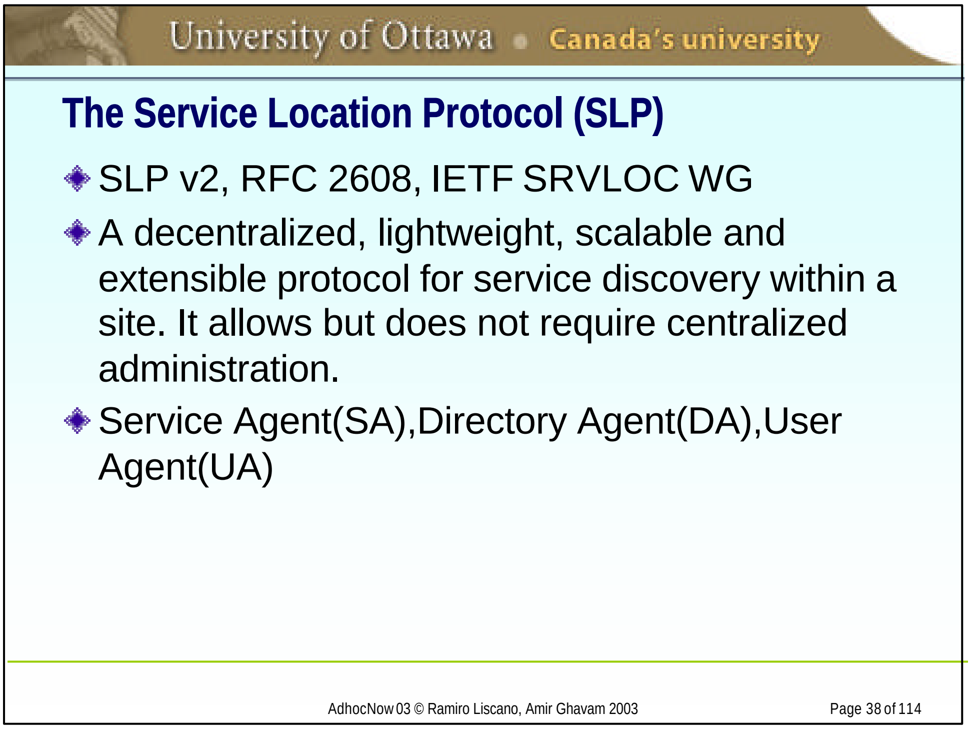
Generic Object Exchange Profile

File Transfer Profile

Object Push Profile

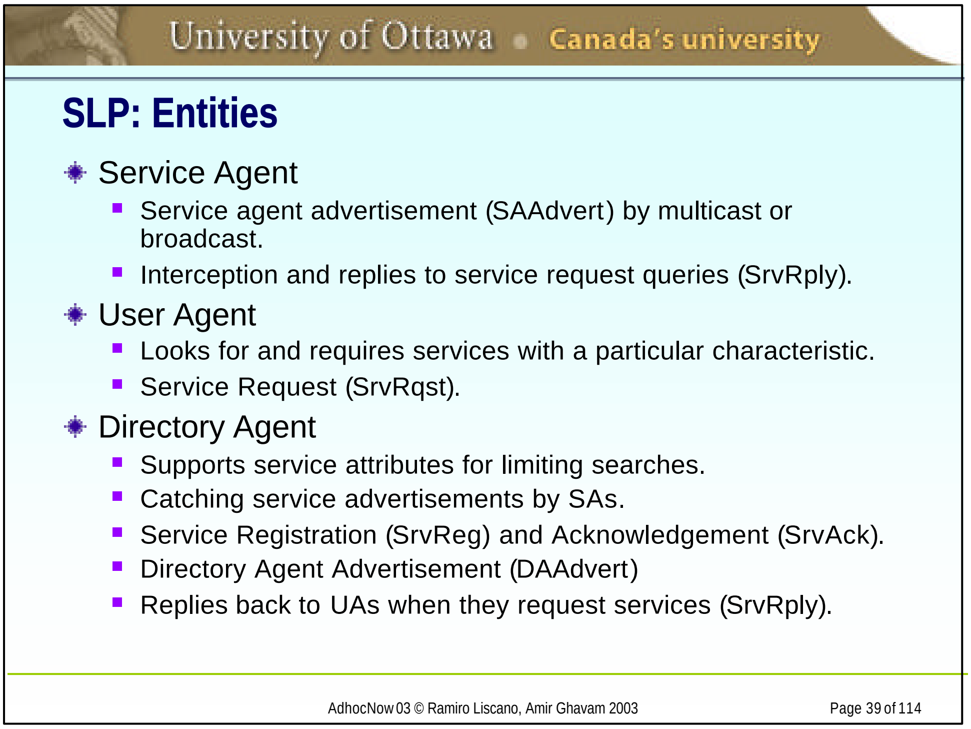
Synchronization Profile

IETF Service Location Protocol (SLP)



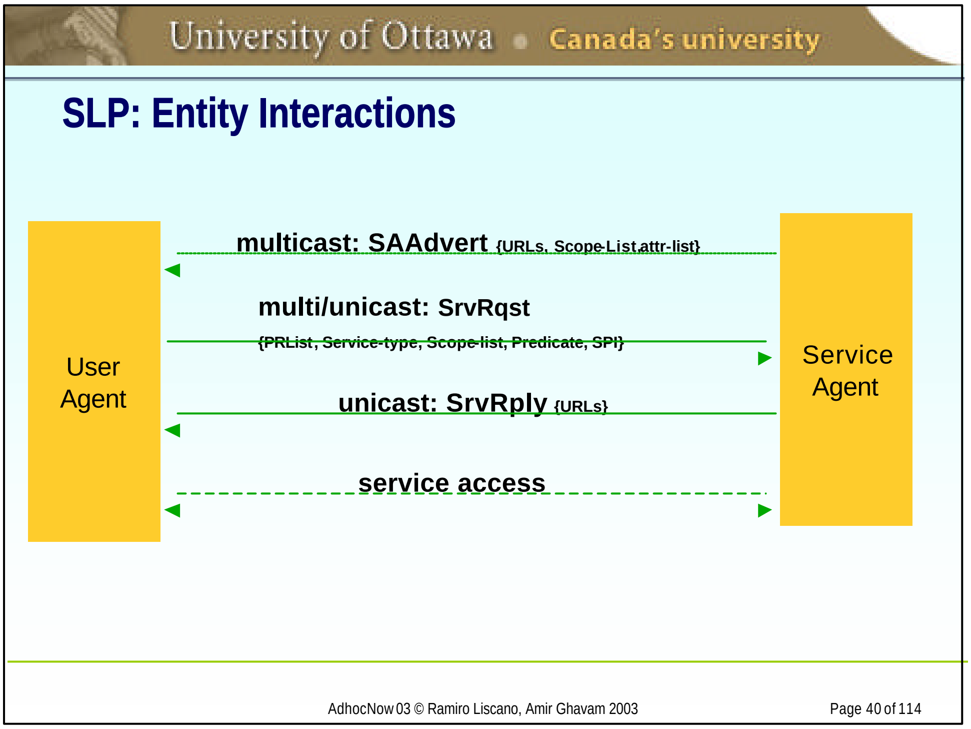
The Service Location Protocol (SLP)

- SLP v2, RFC 2608, IETF SRVLOC WG
- A decentralized, lightweight, scalable and extensible protocol for service discovery within a site. It allows but does not require centralized administration.
- Service Agent(SA),Directory Agent(DA),User Agent(UA)



SLP: Entities

- Service Agent
  - Service agent advertisement (SAAdvert) by multicast or broadcast.
  - Interception and replies to service request queries (SrvRply).
- User Agent
  - Looks for and requires services with a particular characteristic.
  - Service Request (SrvRqst).
- Directory Agent
  - Supports service attributes for limiting searches.
  - Catching service advertisements by SAs.
  - Service Registration (SrvReg) and Acknowledgement (SrvAck).
  - Directory Agent Advertisement (DAAdvert)
  - Replies back to UAs when they request services (SrvRply).



SLP: Entity Interactions

User Agent

Service Agent

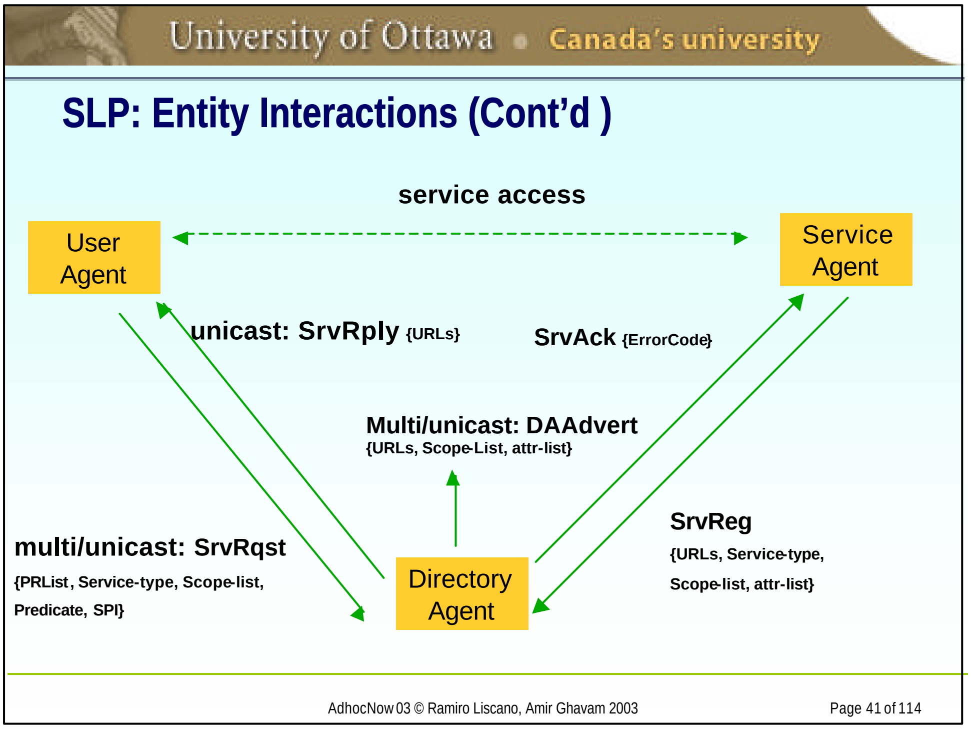
multicast: SAAdvert {URLs, Scope-List,attr-list}

multi/unicast: SrvRqst

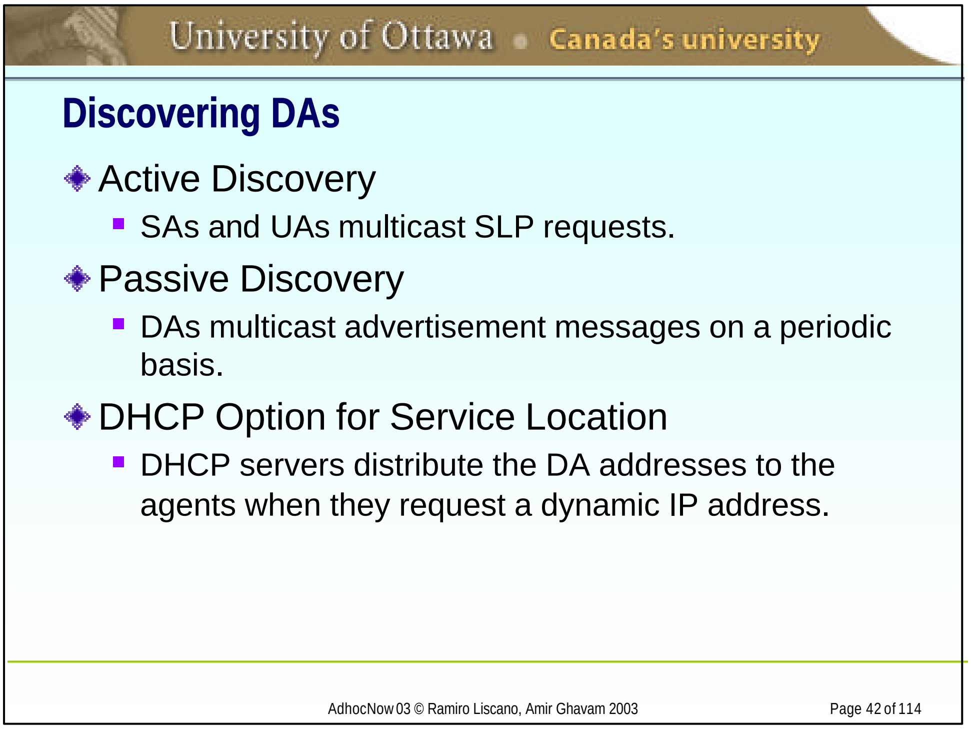
{PRList, Service-type, Scope-list, Predicate, SPI}

unicast: SrvRply {URLs}

service access



SLP: Entity Interactions (Cont'd)



Discovering DAs

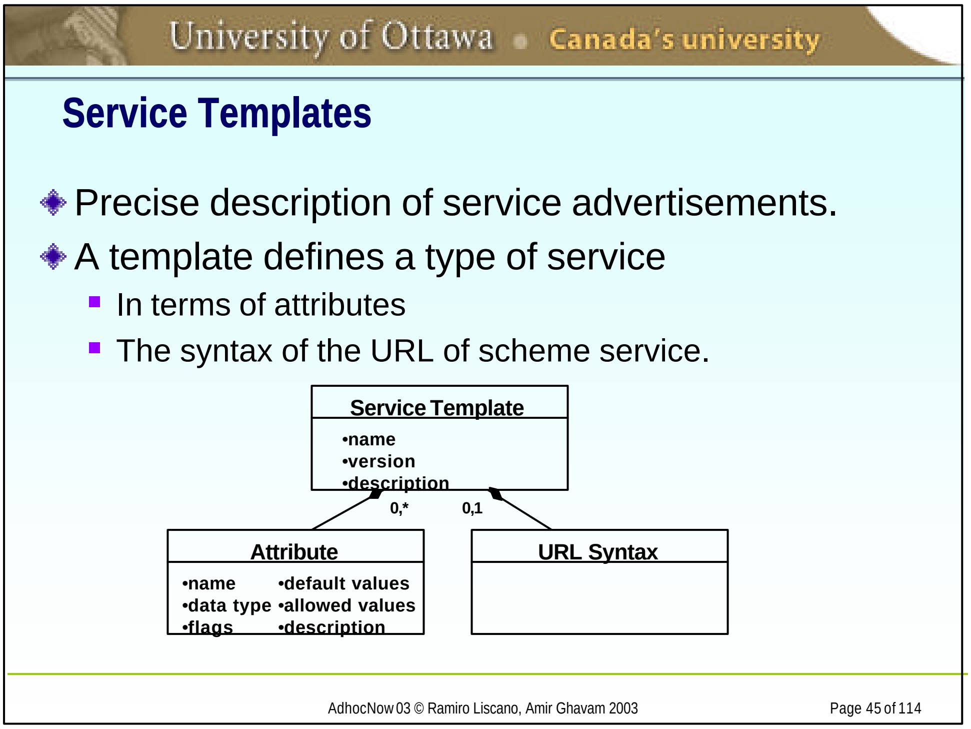
- Active Discovery
  - SAs and UAs multicast SLP requests.
- Passive Discovery
  - DAs multicast advertisement messages on a periodic basis.
- DHCP Option for Service Location
  - DHCP servers distribute the DA addresses to the agents when they request a dynamic IP address.

Scalability (Scopes)

- The primary use of Scopes is to provide the ability to create administrative groupings of services
  - Set of services assigned to a scope.
  - UAs send service requests only to DAs or SAs supporting their scope.
  - All requests except DA and SA discovery requests must contain a scope-list.
- The <scope-list> is a <string-list> of configured scope names. {“Default,STGroup”}

URL Service Access Point Scheme

- Service access points are represented by a special type of URLs.
- Syntax
  - "service:" service-type ":" service-access-info
    - service:lpr://printsrv/queue1(simple service)
    - service:login:rlogin://rndex50.mitel.com (abstract)
    - login is the abstract-type-name and rlogin is a concrete-type-name.
  - Multiple URL access points are allowed.

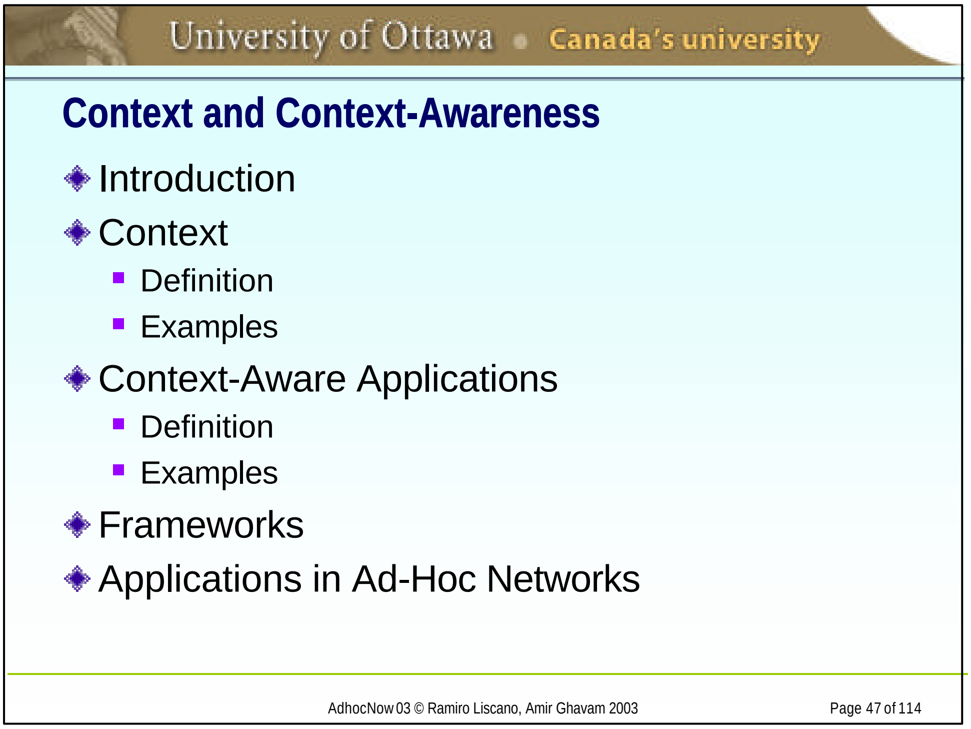


Service Templates

- Precise description of service advertisements.
- A template defines a type of service
  - In terms of attributes
  - The syntax of the URL of scheme service.

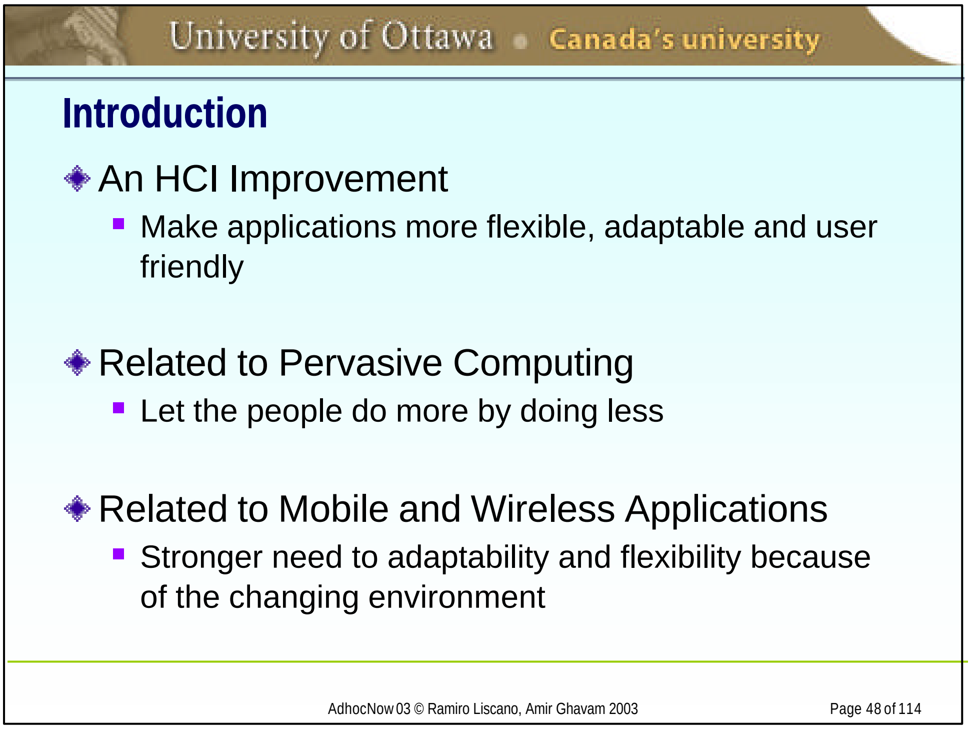
Service Template
•name
•version
•description
0,*
0,1
Attribute
•name
•data type
•flags
•default values
•allowed values
•description
URL Syntax

Context Aware Service Discovery



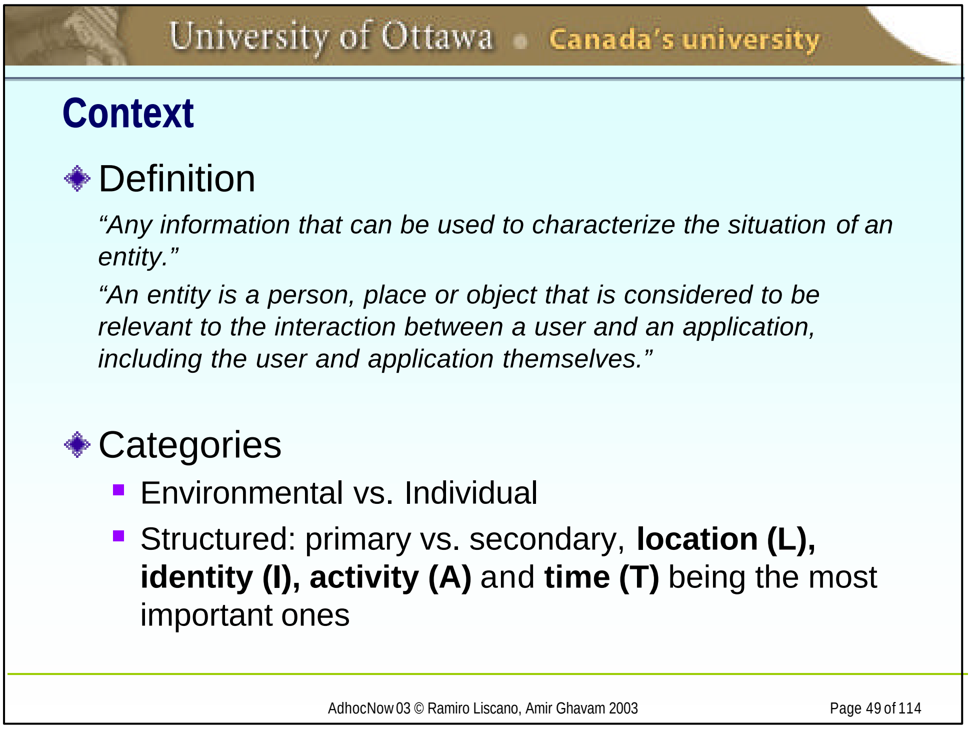
Context and Context-Awareness

- Introduction
- Context
  - Definition
  - Examples
- Context-Aware Applications
  - Definition
  - Examples
- Frameworks
- Applications in Ad-Hoc Networks



Introduction

- An HCI Improvement
  - Make applications more flexible, adaptable and user friendly
- Related to Pervasive Computing
  - Let the people do more by doing less
- Related to Mobile and Wireless Applications
  - Stronger need to adaptability and flexibility because of the changing environment



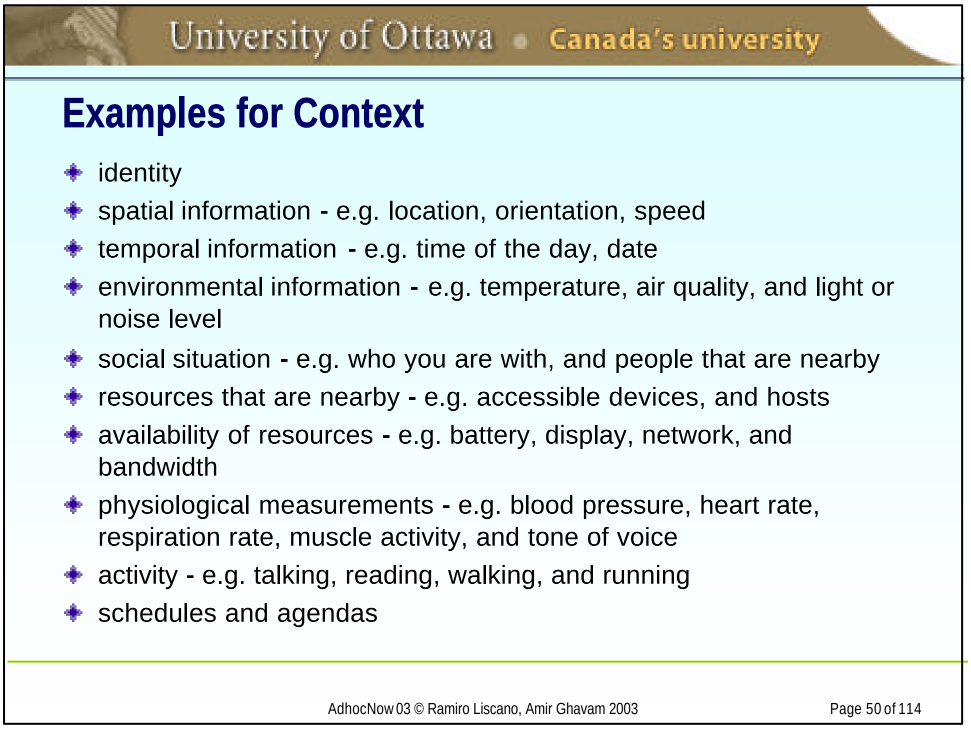
Context

- Definition

  "Any information that can be used to characterize the situation of an entity."

  "An entity is a person, place or object that is considered to be relevant to the interaction between a user and an application, including the user and application themselves."

- Categories
  - Environmental vs. Individual
  - Structured: primary vs. secondary, **location (L), identity (I), activity (A)** and **time (T)** being the most important ones



Examples for Context

- identity
- spatial information - e.g. location, orientation, speed
- temporal information - e.g. time of the day, date
- environmental information - e.g. temperature, air quality, and light or noise level
- social situation - e.g. who you are with, and people that are nearby
- resources that are nearby - e.g. accessible devices, and hosts
- availability of resources - e.g. battery, display, network, and bandwidth
- physiological measurements - e.g. blood pressure, heart rate, respiration rate, muscle activity, and tone of voice
- activity - e.g. talking, reading, walking, and running
- schedules and agendas

Context-Aware Systems/Applications

- Definition

  "A system is context-aware if it uses context to provide relevant information and/or services to the user, where relevancy depends on user's task"

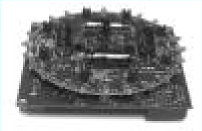
- Categories
  - Presentation of information and services to a user (P)
  - Automatic execution of a service (E)
  - Tagging of context to information for later retrieval (T)

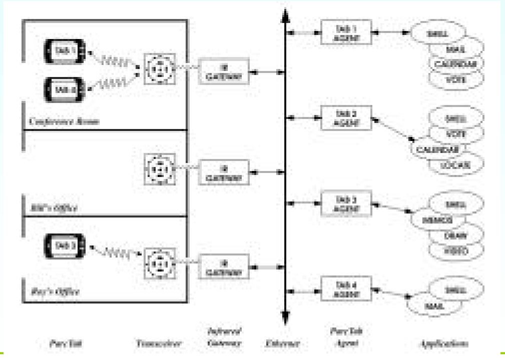
Office Tools: PARCTab System

•Early 90's by Xerox PARC

•Services

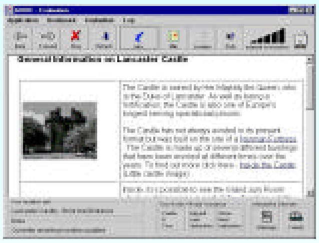
- •Locating People (paging, call forwarding)
- •Reading Email
- •Store Calendar Information
- •Receiving Location Information
- •Locating (Computing) Resources





Tourist Guides: GUIDE

- •Developed by University of Lancaster for visitors of the Lancaster city
- •Provides adaptive information using user profile
- •TeamPad 7600, Win95, Applet
- •WaveLAN, 2 Mbps
- •Linux server in each of 6 cells
- •Mainly for outdoors
- •Being developed for indoors using Bluetooth



General Information on Lancaster Castle

The Castle is owned by Her Majesty the Queen, who is the Duke of Lancaster. As well as being a fortification, the Castle is also one of Europe's longest serving operational prisons.

The Castle has not always existed in its present format but was built on the site of a Norman Fortress. The Castle is made up of several different buildings that have been erected at different times over the years. To find out more click here - Inside the Castle (Little Castle Image)

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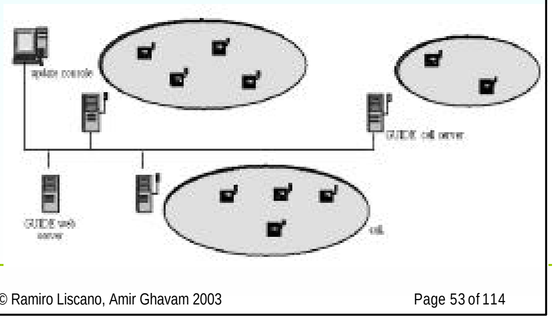
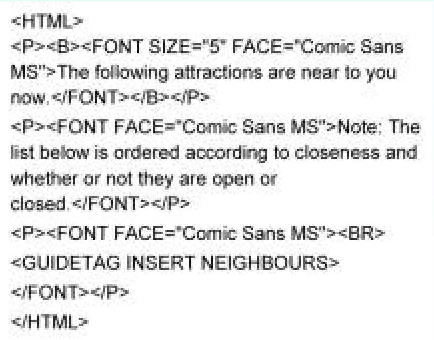


Tourist Guides: GUIDE (Cont'd)



```
<HTML>
<P><B><FONT SIZE="5" FACE="Comic Sans
MS">The following attractions are near to you
now.</FONT></B></P>
<P><FONT FACE="Comic Sans MS">Note: The
list below is ordered according to closeness and
whether or not they are open or
closed.</FONT></P>
<P><FONT FACE="Comic Sans MS"><BR>
<GUIDETAG INSERT NEIGHBOURS>
</FONT></P>
</HTML>
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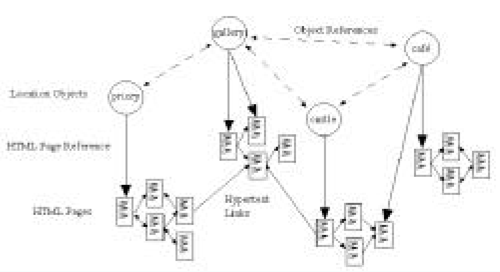
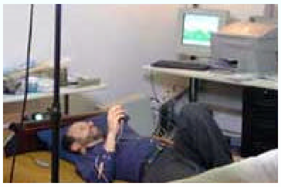


Memory Aids: StartleCam

- Humans remember events by associating them to the context
- Using context for indexing and retrieving
- MIT Media Lab
- Wearable system
- Senses skin conductivity to detect interest
- Captures interesting scenes and stores them on a remote server



Home Usage: Context-Aware Cook

•Shows dishes that can be prepared with available ingredients

•Properties of Ingredients

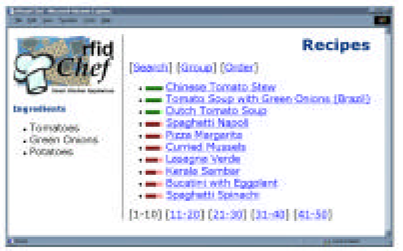
- •Amount
- •Date

•Properties of the kitchen

- •Tools
- •Spices

•Properties of the cook

- •Prefers Asian dishes
- •Expert in vegetarian dishes



rfid Chef

Ingredients

- Tomatoes
- Green Onions
- Potatoes

Recipes

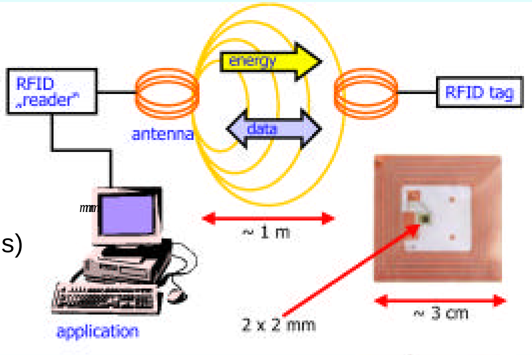
[Search] [Group] [Order]

- 🟩 Chinese Tomato Stew
- 🟩 Tomato Soup with Green Onions (Brazil)
- 🟩 Dutch Tomato Soup
- 🟥 Spaghetti Napoli
- 🟥 Pizza Margarita
- 🟥 Curried Mussels
- 🟥 Lasagne Verde
- 🟥 Kerala Sambar
- 🟥 Bucatini with Eggplant
- 🟥 Spaghetti Spinachi

[1-10] [11-20] [21-30] [31-40] [41-50]

RFID System, Smart Tags

- IC with RF-Transponder
  - Chip 2mm x 2mm x 10µm
- Wireless energy supply
  - ~1 m
  - Magnetic field (induction)
- ROM or EEPROM (100 Bytes)
- Price 0.1$ - 1$
- Flexible Tags
  - Laminated with paper
  - Self adhesive
  - Printable (Barcodes)

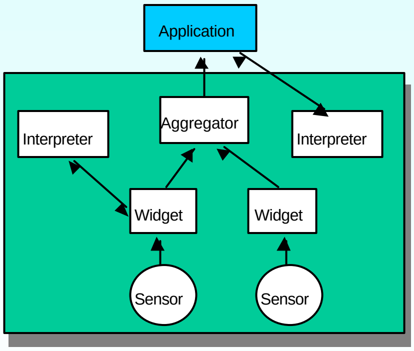


Frameworks: Stick-e Notes

- Developed by University of Kent at Canterbury
- Attaches notes to different types of context
- Activates in the next occurrence of the context
- Note can be text, html-page, sound clip or even executable program
- Contains 3 type of components
  - **Triggering**: for comparing the current context with those of notes
  - **Execution**: for executing the note
  - **Sensor**: for data input
- Uses SGML for data exchange
- Implementation in C++

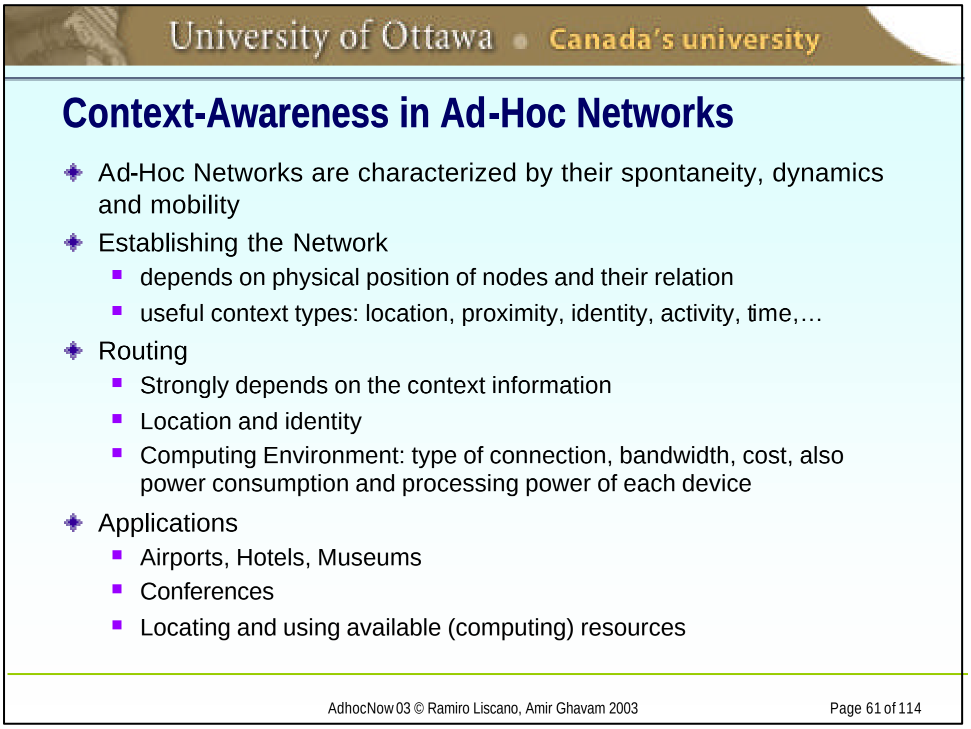
Frameworks: Context-Toolkit

- Developed by GeorgiaTech
- OO-based Approach
  - **Widgets:** Receive context from sensors,Hide complexity
  - **Aggregators** (Servers): Capture all context information of an entity
  - **Interpreters:** Interpreting the context information, Transforming to other forms if required
- HTTP and XML have been used for data exchange but can be replaced
- Implementation in Java available



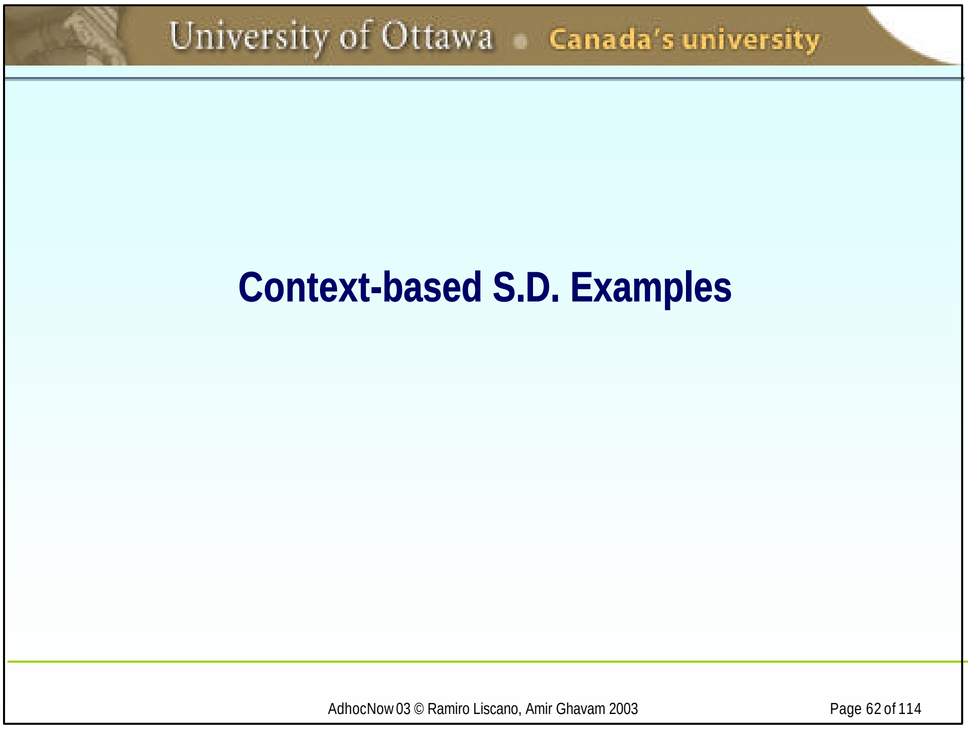
Application of Categories

System Name	System Description	Context Type				Context-Aware		
		A	I	L	T	P	E	T
Classroom 2000	Capture of classroom lecture			X	X			X
Cyberguide	Tour guide		X	X		X		
Teleport	Teleporting	X	X	X			X	
Stick-e Documents	Tour guide		X	X		X		X
	Paging and reminders	X	X			X		X
Reactive Room	Intelligent control of audiovisuals	X	X	X			X	
GUIDE	Tour guide			X		X		
CyberDesk	Automatic integration of user services	X				X	X	
Conference Assistant	Conference capture and tour guide	X	X	X	X	X		X
Responsive Office	Office environment control			X	X		X	
NETMAN	Network maintenance			X		X		
Fieldwork	Fieldwork data collection			X	X	X		X
Augment-able Reality	Virtual post-it notes			X		X		X
Context Toolkit	In/Out Board		X	X	X	X		
	Capture of serendipitous meetings		X	X	X		X	X
Active Badge	Call forwarding		X	X		X	X	



Context-Awareness in Ad-Hoc Networks

- Ad-Hoc Networks are characterized by their spontaneity, dynamics and mobility
- Establishing the Network
  - depends on physical position of nodes and their relation
  - useful context types: location, proximity, identity, activity, time,…
- Routing
  - Strongly depends on the context information
  - Location and identity
  - Computing Environment: type of connection, bandwidth, cost, also power consumption and processing power of each device
- Applications
  - Airports, Hotels, Museums
  - Conferences
  - Locating and using available (computing) resources



Context-based S.D. Examples

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Proximity-based Service Discovery.

- Facilitating Service Discovery Using Proximity Sensing … (V. Azondekon, et al.)
- Two infrared-based protocols were developed for facilitating service discovery that leveraged the IETF SLP protocol and Infrared communications.
  - SetIrdaLink (based on the IrDA protocol.
  - IDAdvert (based solely on IR).
- Looking for best service in a multi-media IP phone set.
- SLP modified to include new proximity protocols.

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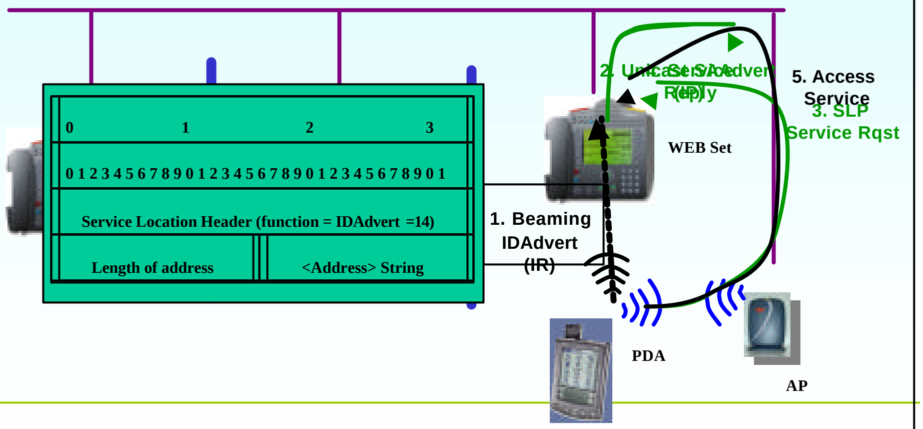
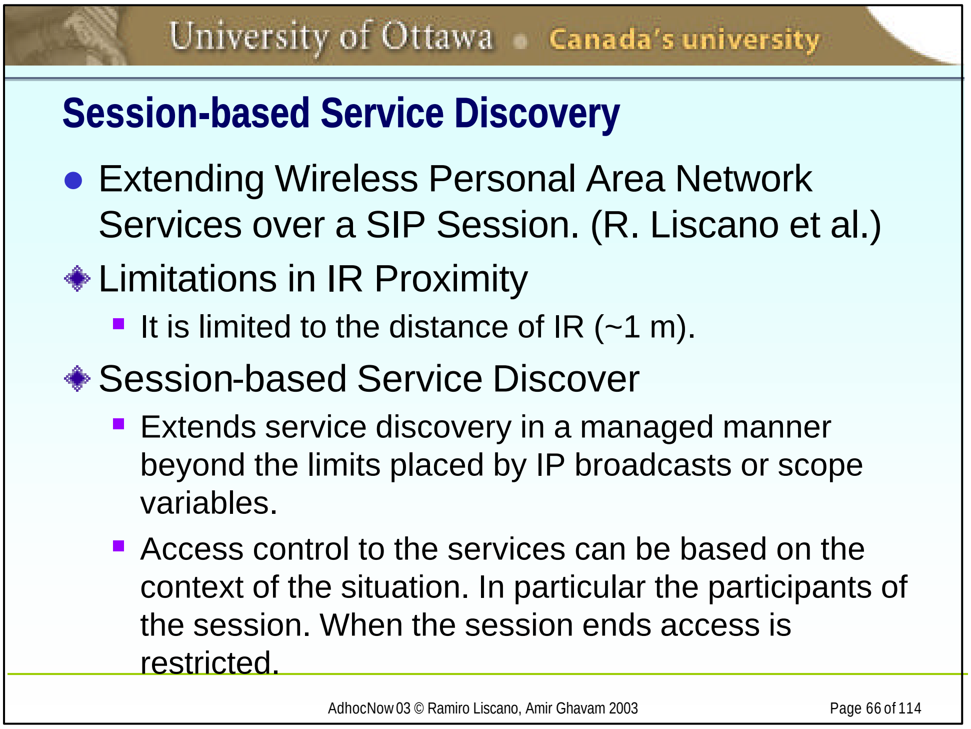
The IDAvert protocol

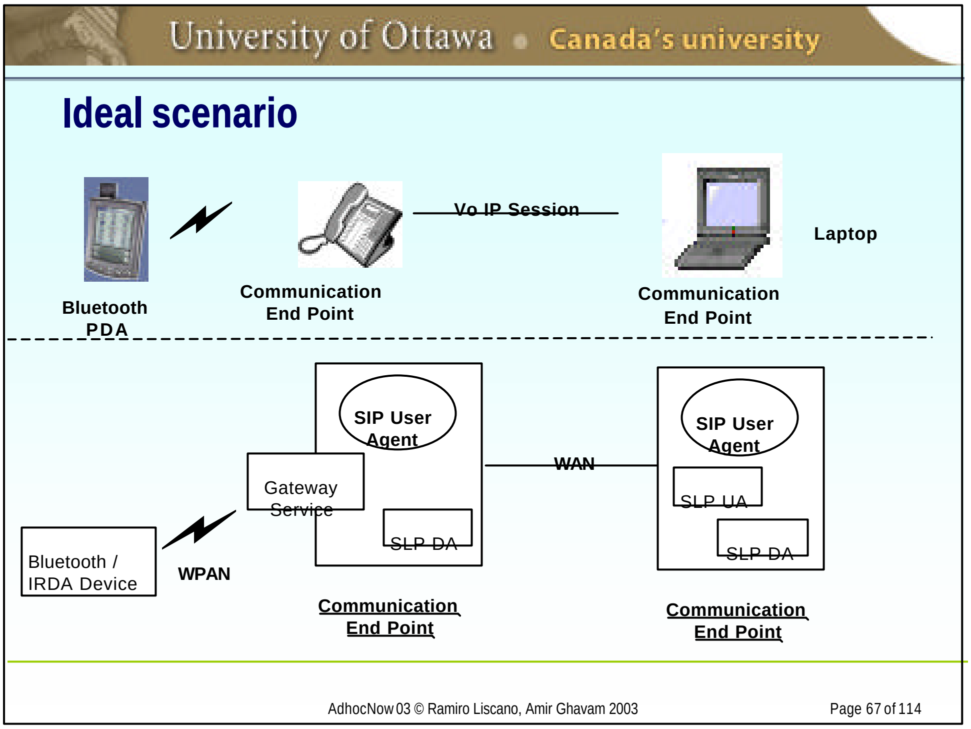


0	1	2	3
0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1
Service Location Header (function = IDAdvert =14)			
Length of address		<Address> String	



Session-based Service Discovery

- Extending Wireless Personal Area Network Services over a SIP Session. (R. Liscano et al.)
- Limitations in IR Proximity
  - It is limited to the distance of IR (~1 m).
- Session-based Service Discover
  - Extends service discovery in a managed manner beyond the limits placed by IP broadcasts or scope variables.
  - Access control to the services can be based on the context of the situation. In particular the participants of the session. When the session ends access is restricted.



Ideal scenario

Bluetooth PDA

Communication End Point

Vo IP Session

Laptop

Communication End Point

SIP User Agent

Gateway Service

SLP DA

WAN

SIP User Agent

SLP UA

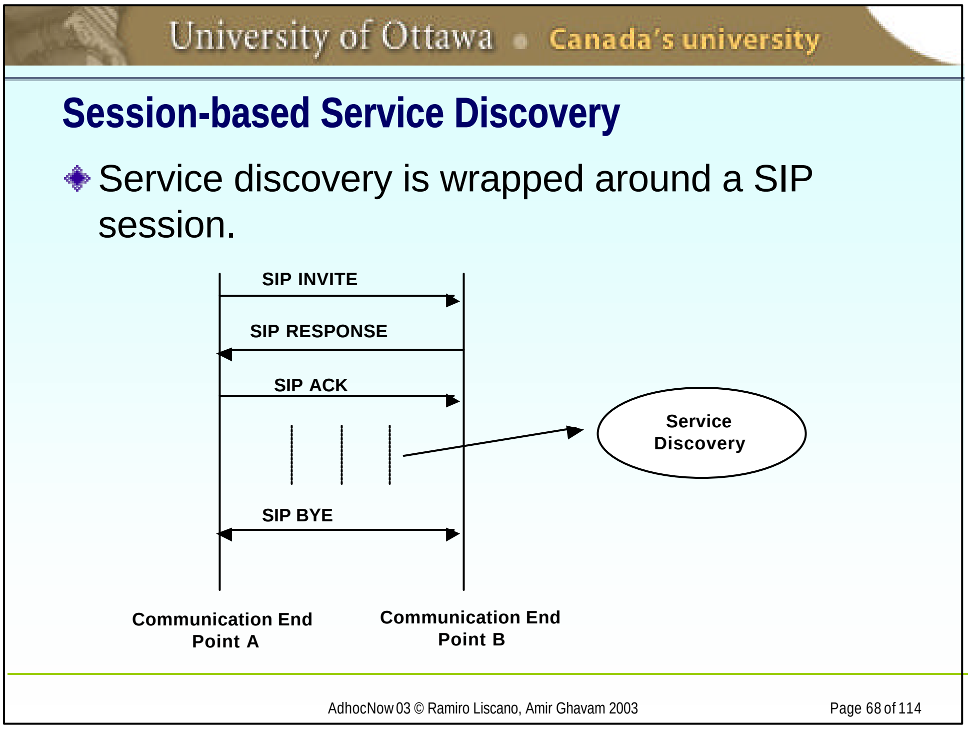
SLP DA

Bluetooth / IRDA Device

WPAN

Communication End Point

Communication End Point



Session-based Service Discovery

- Service discovery is wrapped around a SIP session.

SIP INVITE

SIP RESPONSE

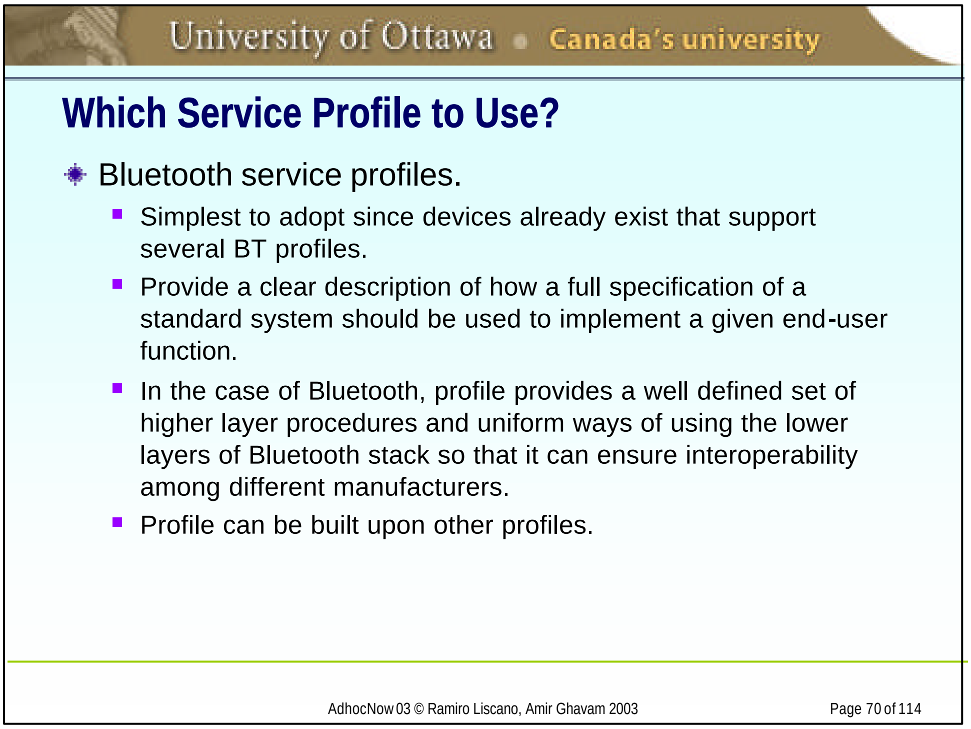
SIP ACK

Service Discovery

SIP BYE

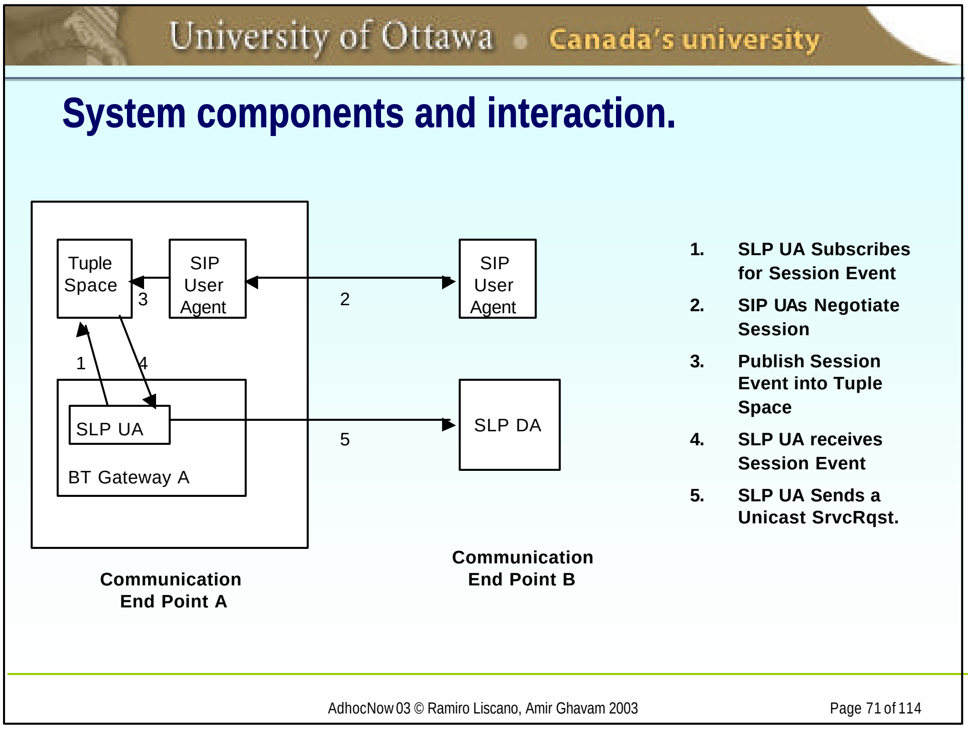
Communication End Point A

Communication End Point B



Which Service Profile to Use?

- Bluetooth service profiles.
  - Simplest to adopt since devices already exist that support several BT profiles.
  - Provide a clear description of how a full specification of a standard system should be used to implement a given end-user function.
  - In the case of Bluetooth, profile provides a well defined set of higher layer procedures and uniform ways of using the lower layers of Bluetooth stack so that it can ensure interoperability among different manufacturers.
  - Profile can be built upon other profiles.



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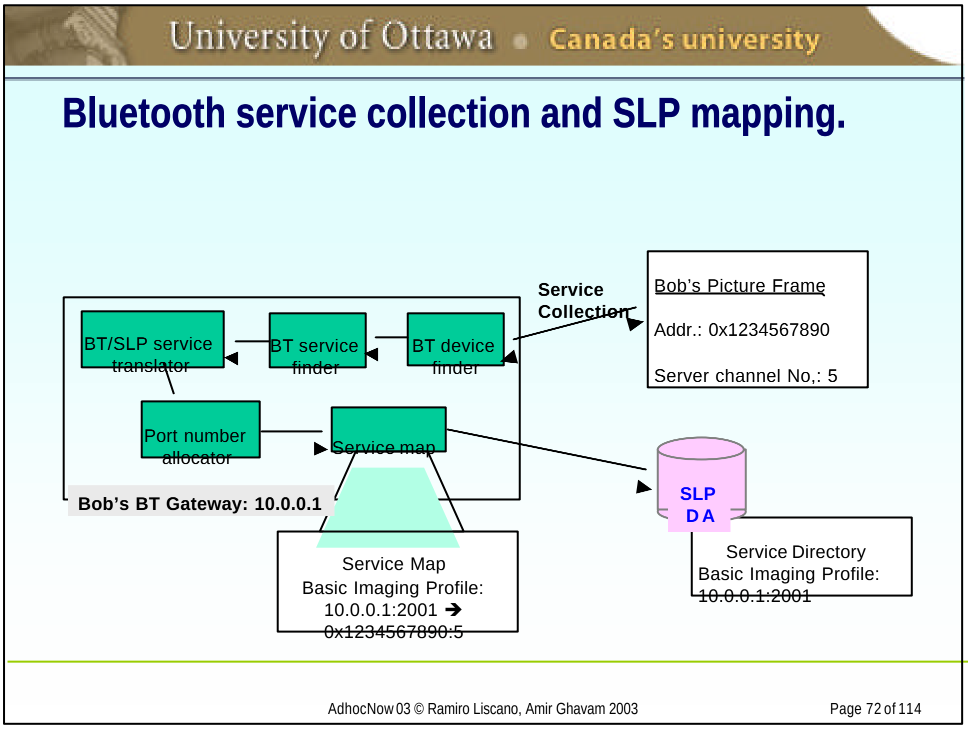
System components and interaction.

1. SLP UA Subscribes for Session Event
2. SIP UAs Negotiate Session
3. Publish Session Event into Tuple Space
4. SLP UA receives Session Event
5. SLP UA Sends a Unicast SrvcRqst.

Communication End Point A

Communication End Point B



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Bluetooth service collection and SLP mapping.

Bob's Picture Frame

Addr.: 0x1234567890

Server channel No,: 5

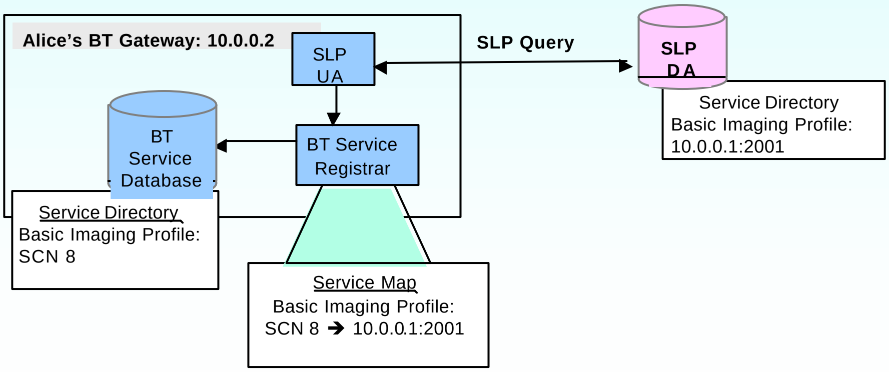
Bob's BT Gateway: 10.0.0.1

Service Map
Basic Imaging Profile:
10.0.0.1:2001 → 0x1234567890:5

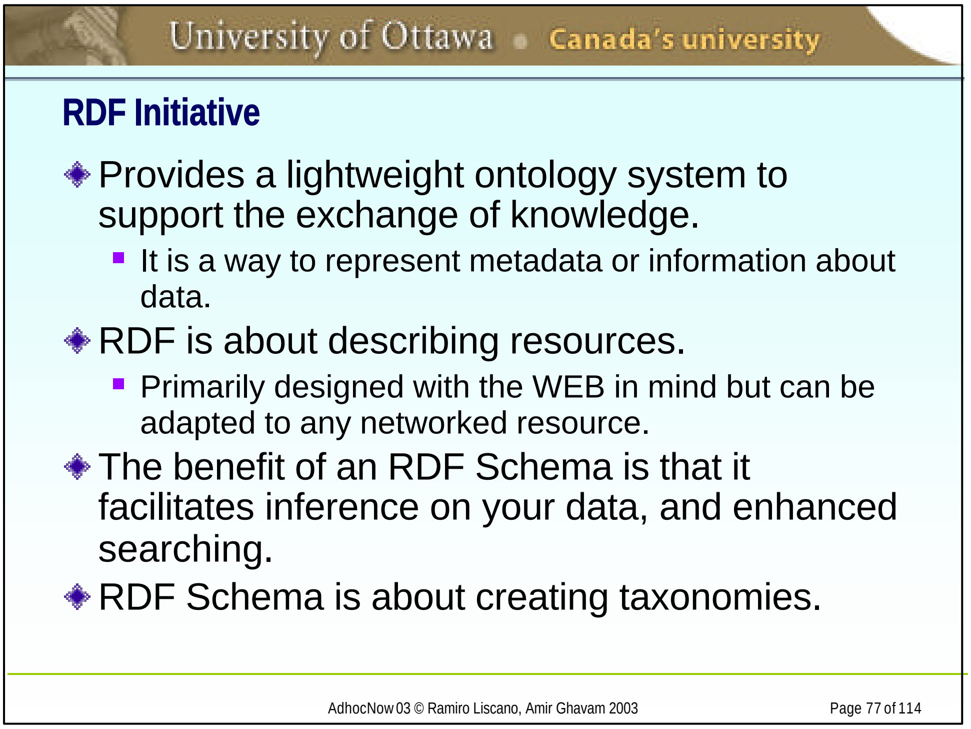
Service Directory
Basic Imaging Profile:
10.0.0.1:2001

Example of a Session-based Service Discovery

- SLP service collection and BT mapping.

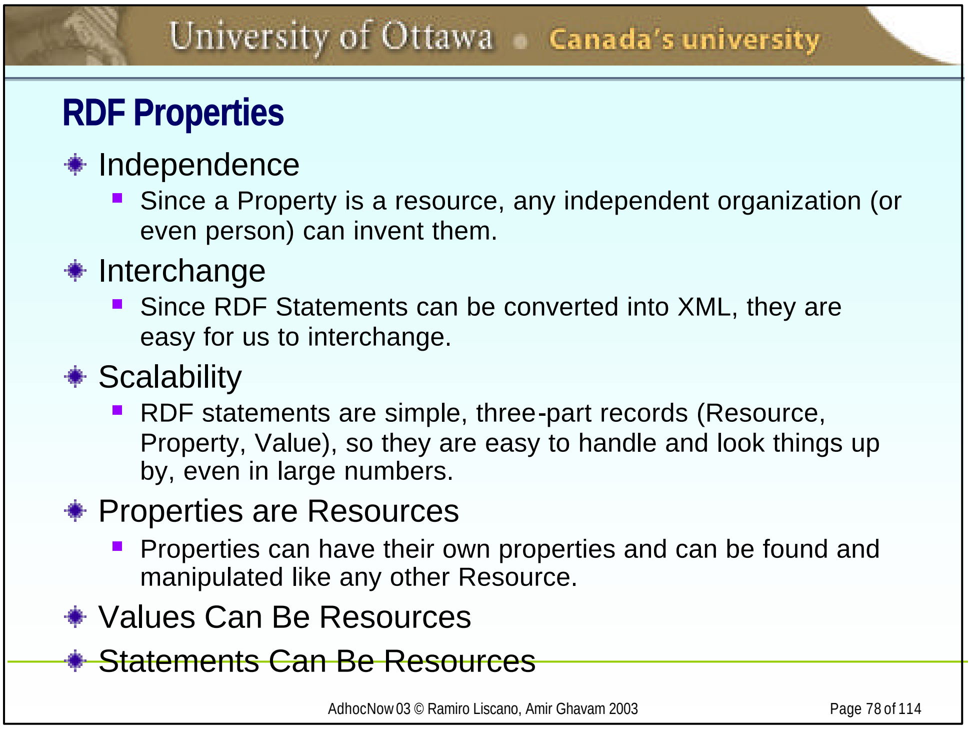


Semantic Service Discovery



RDF Initiative

- Provides a lightweight ontology system to support the exchange of knowledge.
  - It is a way to represent metadata or information about data.
- RDF is about describing resources.
  - Primarily designed with the WEB in mind but can be adapted to any networked resource.
- The benefit of an RDF Schema is that it facilitates inference on your data, and enhanced searching.
- RDF Schema is about creating taxonomies.



RDF Properties

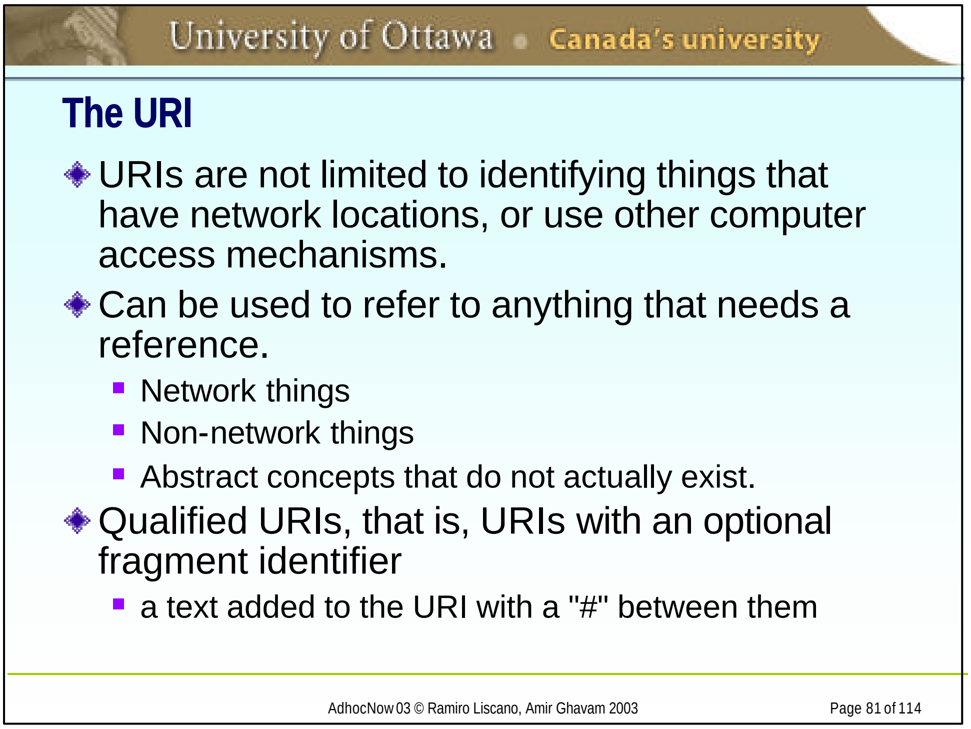
- Independence
  - Since a Property is a resource, any independent organization (or even person) can invent them.
- Interchange
  - Since RDF Statements can be converted into XML, they are easy for us to interchange.
- Scalability
  - RDF statements are simple, three-part records (Resource, Property, Value), so they are easy to handle and look things up by, even in large numbers.
- Properties are Resources
  - Properties can have their own properties and can be found and manipulated like any other Resource.
- Values Can Be Resources
- Statements Can Be Resources

Why define an RDF Schema

- RDF Schema is all about **semantics**.
  - XML Schemas is all about **syntax**.
- An RDF Schema tool is intended to **provide additional facts** beyond the tags defined in the RDF/XML instances.
  - Other service templates use an XML Schema that is intended to **validate** that an XML instance conforms to the syntax specified by the XML Schema.
- RDF Schemas are **descriptive** - an RDF Schema simply describes classes and properties.
  - XML Schemas used other service templates are **prescriptive** - they prescribe what an element may contain, and the order the child elements may occur.

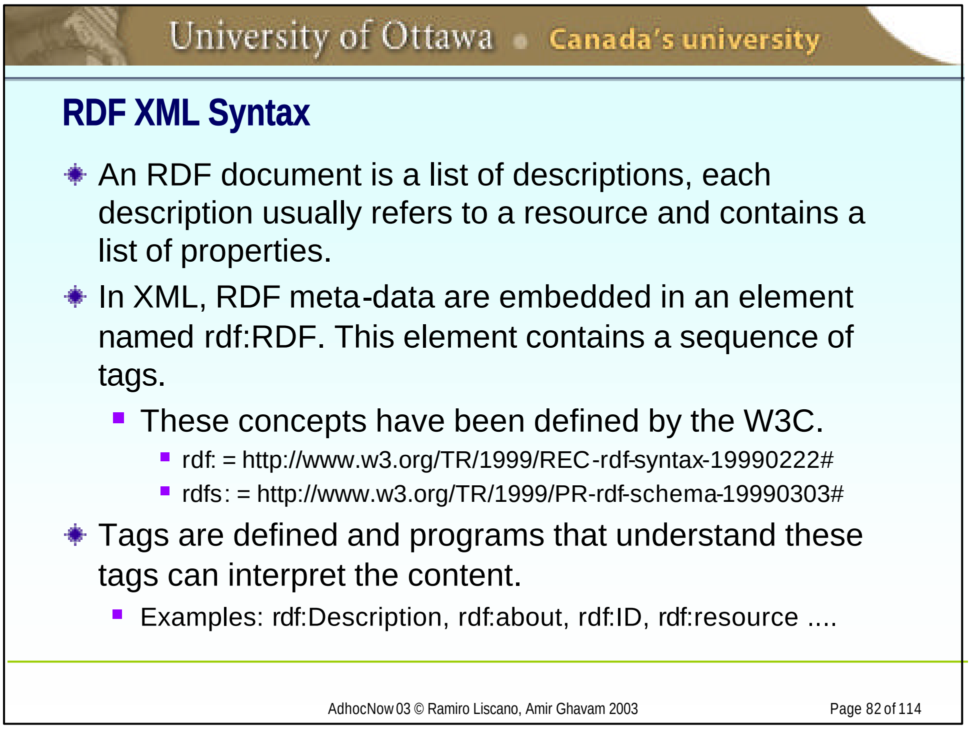
RDF Parts

- The base object is considered a triple.
  - The <Subject> has a property <Predicate> valued by <Object>.
- Subject
  - the part that identifies the thing the statement is about
- Predicate
  - The part that identifies the property or characteristic of the subject
- Object
  - the part that identifies the value of that property
- A resource must be identified by a URI.



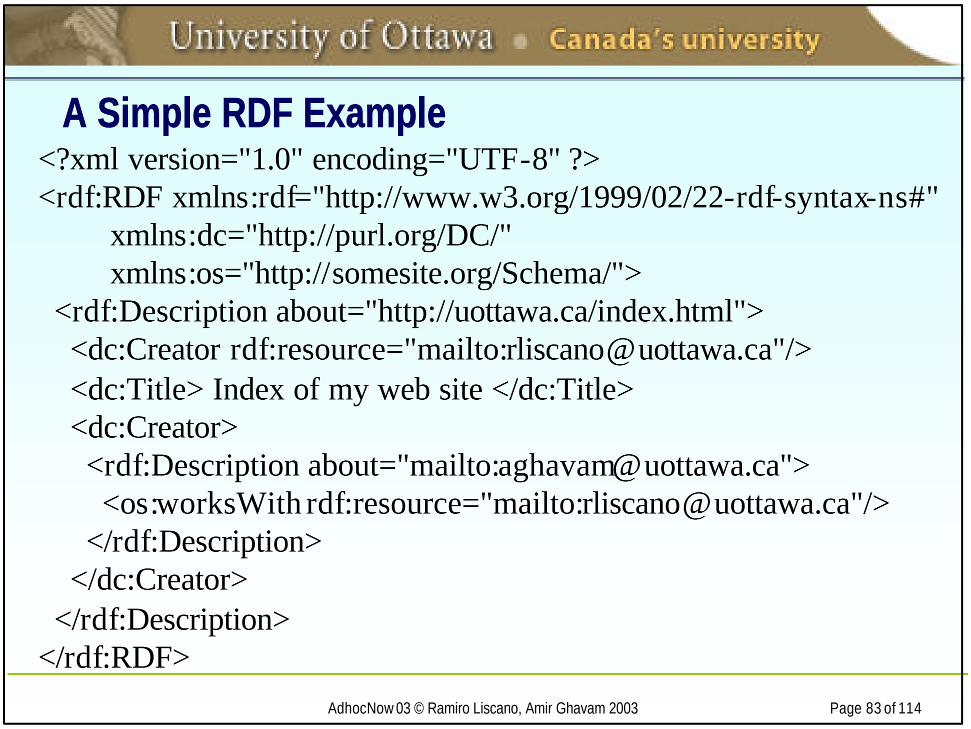
The URI

- URIs are not limited to identifying things that have network locations, or use other computer access mechanisms.
- Can be used to refer to anything that needs a reference.
  - Network things
  - Non-network things
  - Abstract concepts that do not actually exist.
- Qualified URIs, that is, URIs with an optional fragment identifier
  - a text added to the URI with a "#" between them



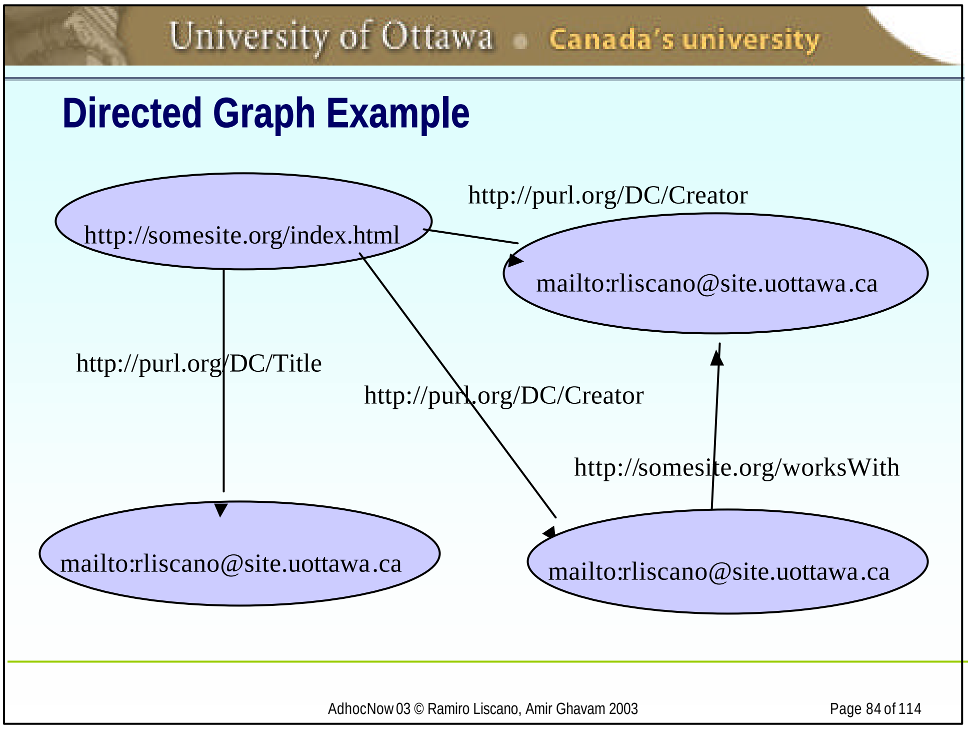
RDF XML Syntax

- An RDF document is a list of descriptions, each description usually refers to a resource and contains a list of properties.
- In XML, RDF meta-data are embedded in an element named rdf:RDF. This element contains a sequence of tags.
  - These concepts have been defined by the W3C.
    - rdf: = http://www.w3.org/TR/1999/REC-rdf-syntax-19990222#
    - rdfs: = http://www.w3.org/TR/1999/PR-rdf-schema-19990303#
- Tags are defined and programs that understand these tags can interpret the content.
  - Examples: rdf:Description, rdf:about, rdf:ID, rdf:resource ....



A Simple RDF Example

```
<?xml version="1.0" encoding="UTF-8" ?>
<rdf:RDF xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
        xmlns:dc="http://purl.org/DC/"
        xmlns:os="http://somesite.org/Schema/">
  <rdf:Description about="http://uottawa.ca/index.html">
    <dc:Creator rdf:resource="mailto:rliscano@uottawa.ca"/>
    <dc:Title> Index of my web site </dc:Title>
    <dc:Creator>
      <rdf:Description about="mailto:aghavam@uottawa.ca">
        <os:worksWith rdf:resource="mailto:rliscano@uottawa.ca"/>
      </rdf:Description>
    </dc:Creator>
  </rdf:Description>
</rdf:RDF>
```



Directed Graph Example

http://somesite.org/index.html

http://purl.org/DC/Creator

mailto:rliscano@site.uottawa.ca

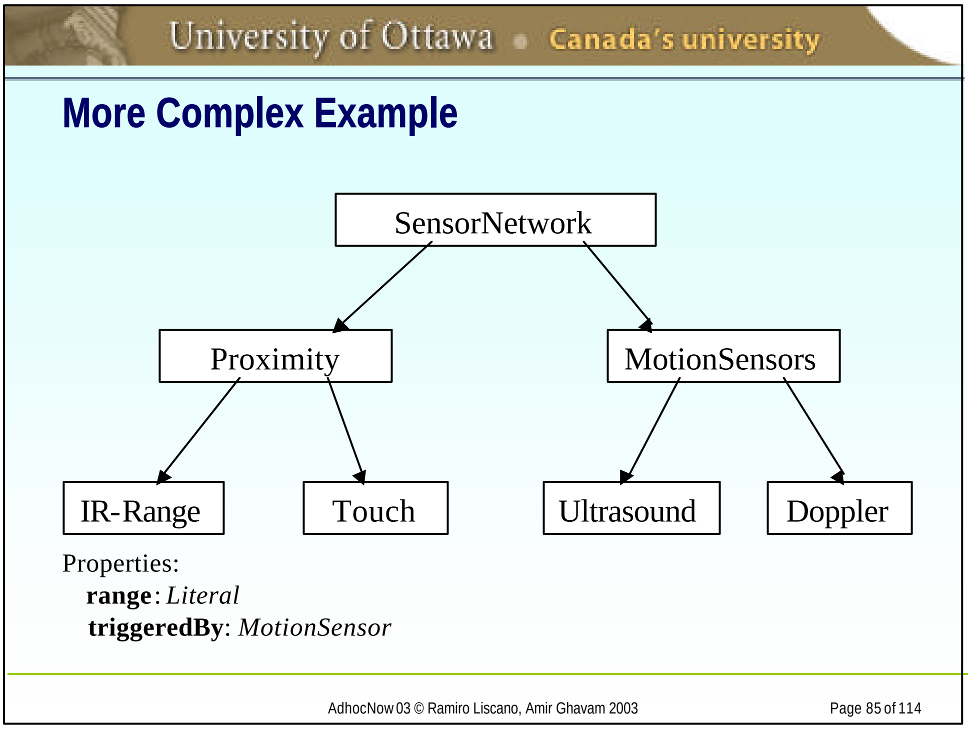
http://purl.org/DC/Title

http://purl.org/DC/Creator

http://somesite.org/worksWith

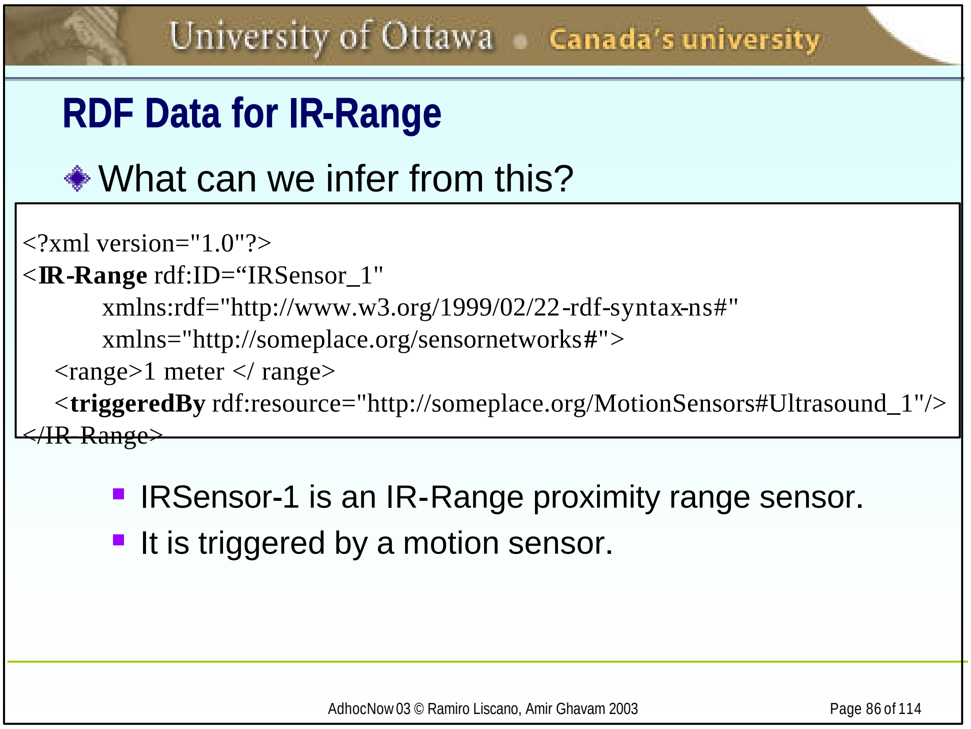
mailto:rliscano@site.uottawa.ca

mailto:rliscano@site.uottawa.ca



More Complex Example

Properties:
range: *Literal*
triggeredBy: *MotionSensor*

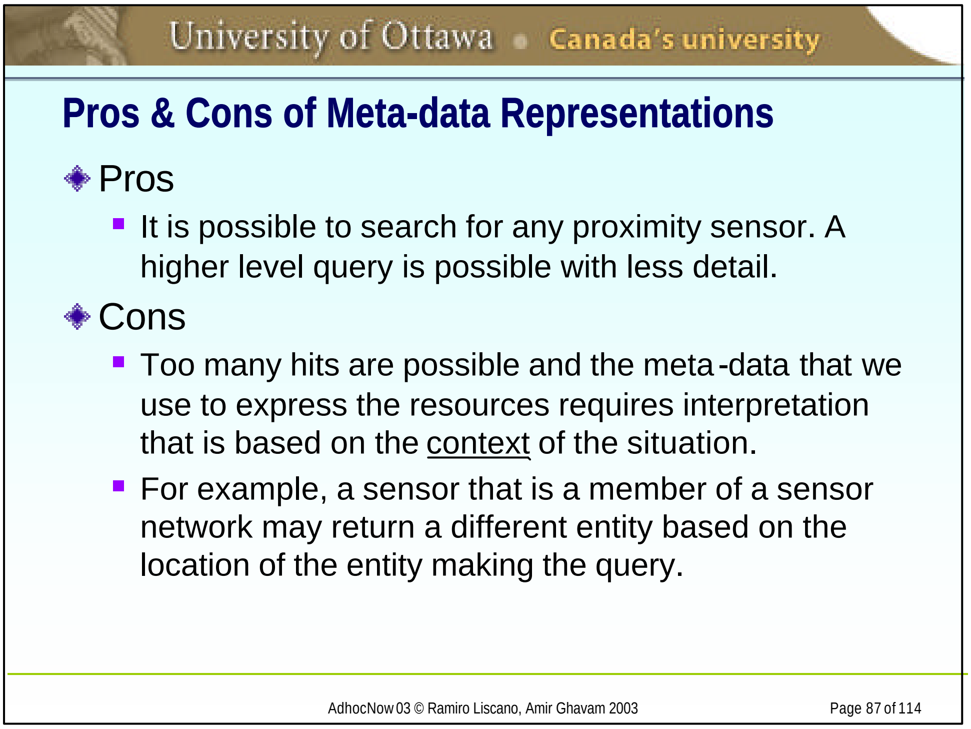


RDF Data for IR-Range

- What can we infer from this?

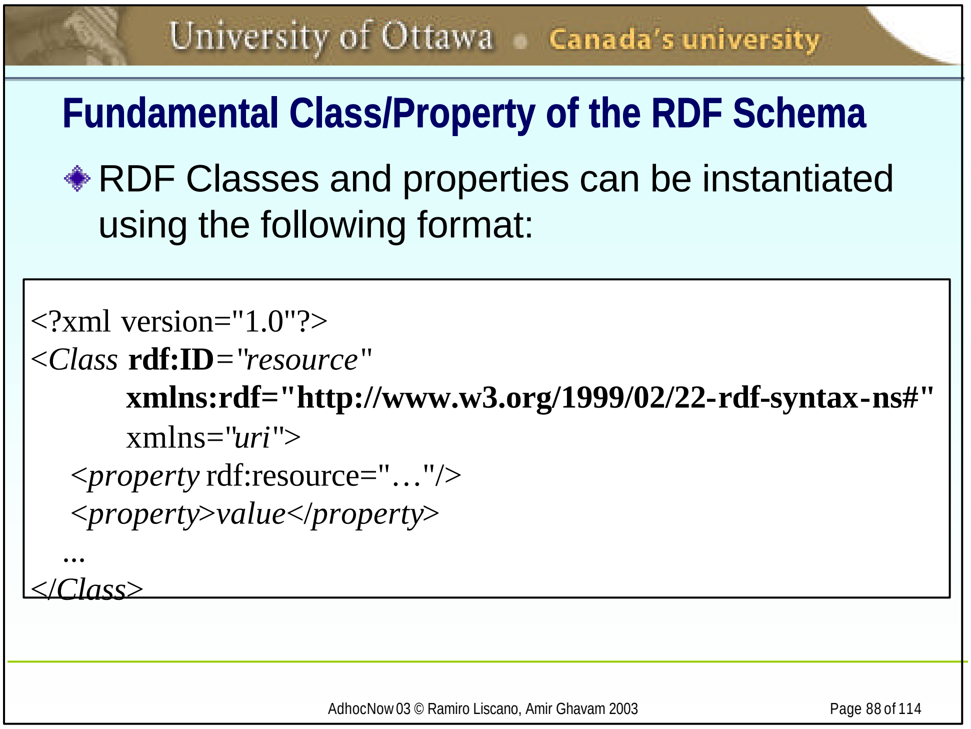
```
<?xml version="1.0"?>
<IR-Range rdf:ID="IRSensor_1"
        xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
        xmlns="http://someplace.org/sensornetworks#">
   <range>1 meter </ range>
   <triggeredBy rdf:resource="http://someplace.org/MotionSensors#Ultrasound_1"/>
</IR-Range>
```

- IRSensor-1 is an IR-Range proximity range sensor.
- It is triggered by a motion sensor.



Pros & Cons of Meta-data Representations

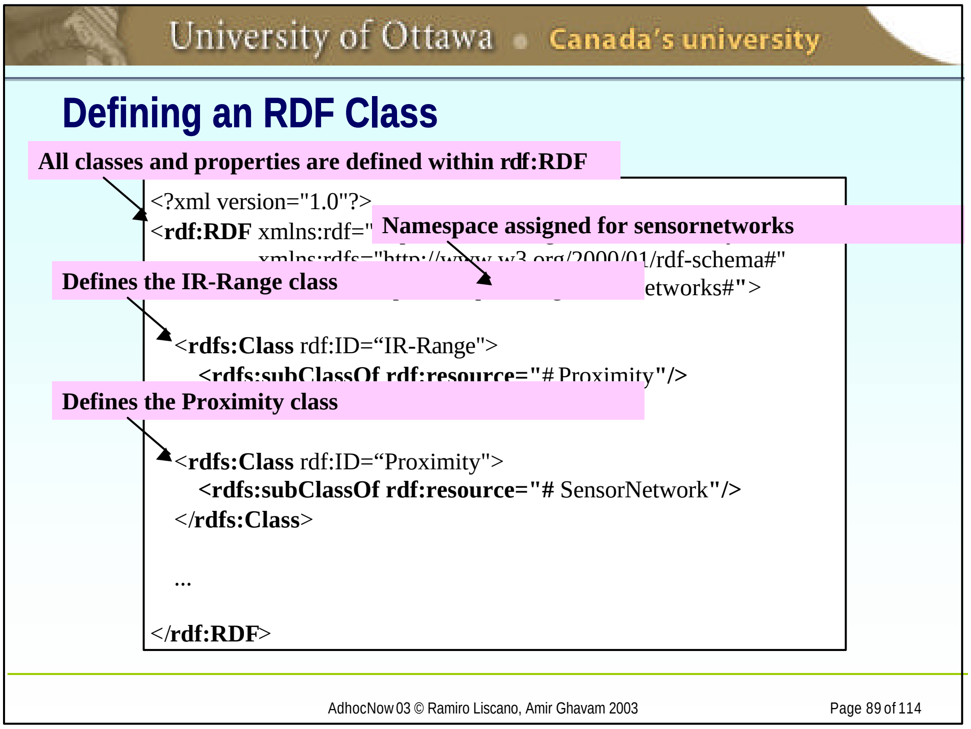
- Pros
  - It is possible to search for any proximity sensor. A higher level query is possible with less detail.
- Cons
  - Too many hits are possible and the meta-data that we use to express the resources requires interpretation that is based on the context of the situation.
  - For example, a sensor that is a member of a sensor network may return a different entity based on the location of the entity making the query.



Fundamental Class/Property of the RDF Schema

- RDF Classes and properties can be instantiated using the following format:

```
<?xml version="1.0"?>
<Class rdf:ID="resource"
          xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
          xmlns="uri">
    <property rdf:resource="…"/>
    <property>value</property>
   ...
</Class>
```



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Defining an RDF Class

All classes and properties are defined within rdf:RDF

Namespace assigned for sensornetworks

Defines the IR-Range class

Defines the Proximity class

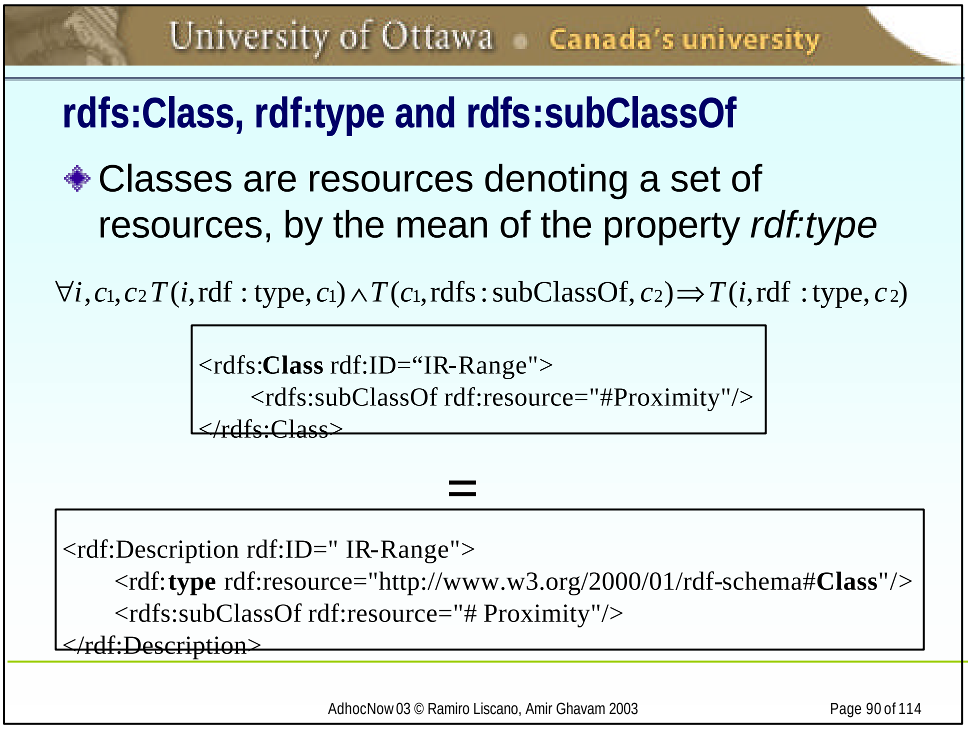
```
<?xml version="1.0"?>
<rdf:RDF xmlns:rdf="
               xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#"
                                                      etworks#">

   <rdfs:Class rdf:ID="IR-Range">
      <rdfs:subClassOf rdf:resource="# Proximity"/>

   <rdfs:Class rdf:ID="Proximity">
      <rdfs:subClassOf rdf:resource="# SensorNetwork"/>
   </rdfs:Class>

   ...

</rdf:RDF>
```



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rdfs:Class, rdf:type and rdfs:subClassOf

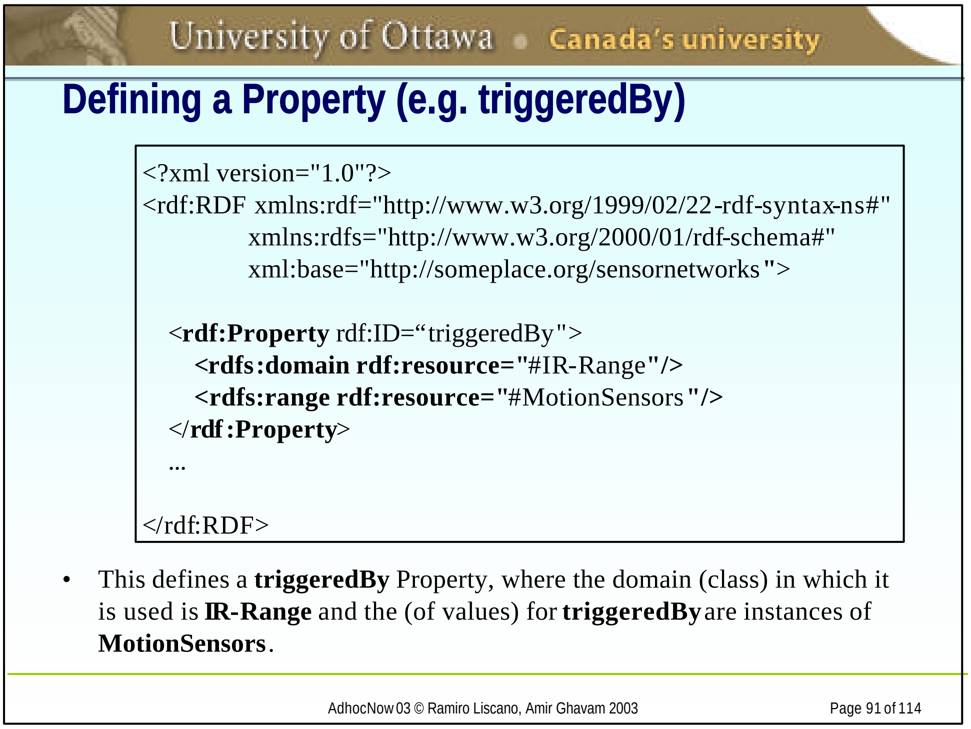
- Classes are resources denoting a set of resources, by the mean of the property *rdf:type*

$$\forall i, c_1, c_2\, T(i, \mathrm{rdf:type}, c_1) \wedge T(c_1, \mathrm{rdfs:subClassOf}, c_2) \Rightarrow T(i, \mathrm{rdf\ :type}, c_2)$$

```
<rdfs:Class rdf:ID="IR-Range">
       <rdfs:subClassOf rdf:resource="#Proximity"/>
</rdfs:Class>
```

=

```
<rdf:Description rdf:ID=" IR-Range">
       <rdf:type rdf:resource="http://www.w3.org/2000/01/rdf-schema#Class"/>
       <rdfs:subClassOf rdf:resource="# Proximity"/>
</rdf:Description>
```



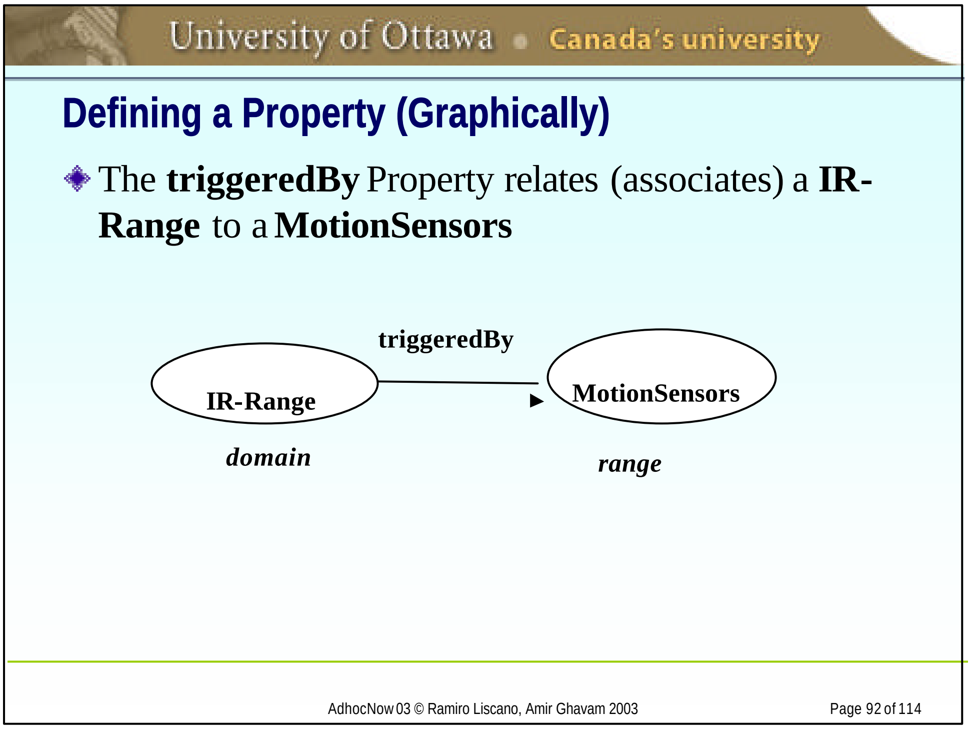
Defining a Property (e.g. triggeredBy)

```
<?xml version="1.0"?>
<rdf:RDF xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
          xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#"
          xml:base="http://someplace.org/sensornetworks">

   <rdf:Property rdf:ID="triggeredBy">
      <rdfs:domain rdf:resource="#IR-Range"/>
      <rdfs:range rdf:resource="#MotionSensors"/>
   </rdf:Property>
   ...

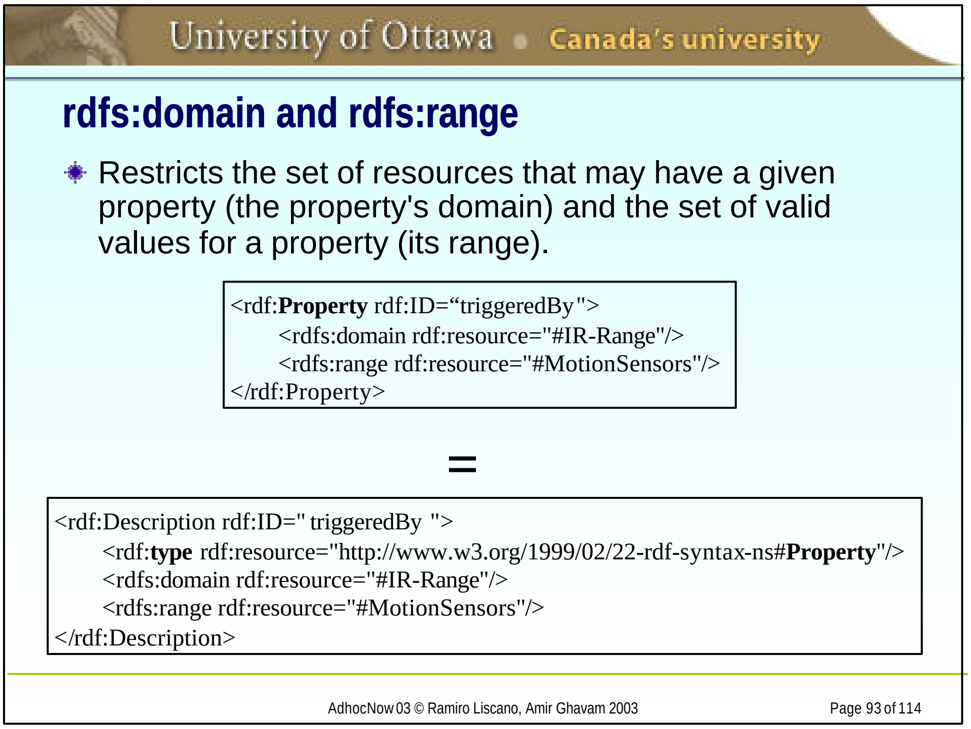
</rdf:RDF>
```

- This defines a **triggeredBy** Property, where the domain (class) in which it is used is **IR-Range** and the (of values) for **triggeredBy** are instances of **MotionSensors**.



Defining a Property (Graphically)

- The **triggeredBy** Property relates (associates) a **IR-Range** to a **MotionSensors**



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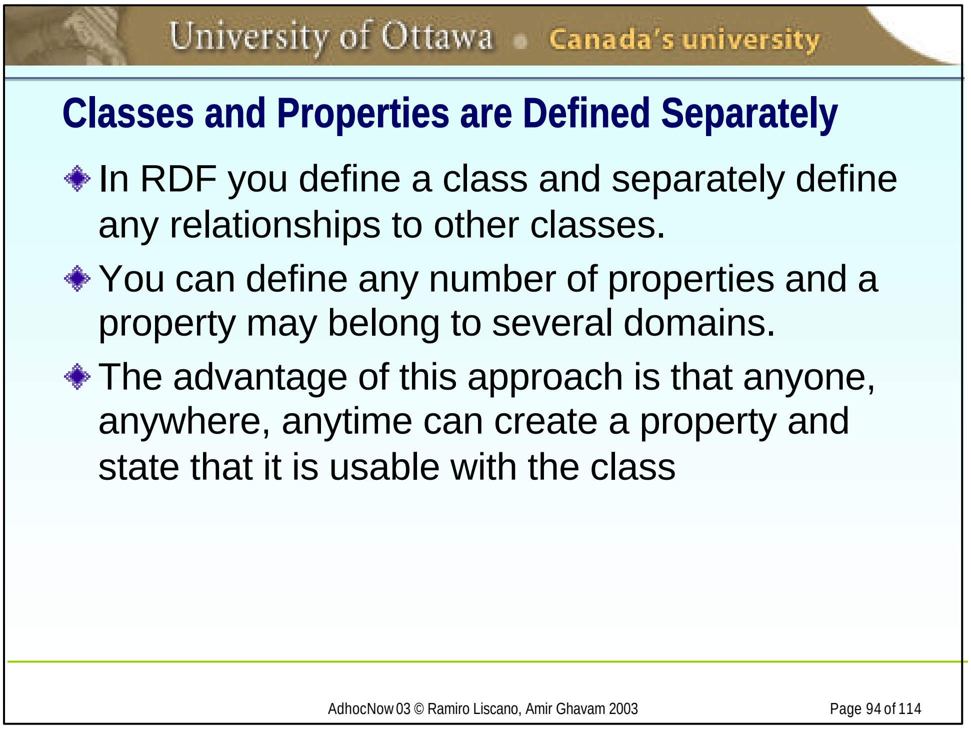
rdfs:domain and rdfs:range

- Restricts the set of resources that may have a given property (the property's domain) and the set of valid values for a property (its range).

```
<rdf:Property rdf:ID=“triggeredBy">
      <rdfs:domain rdf:resource="#IR-Range"/>
      <rdfs:range rdf:resource="#MotionSensors"/>
</rdf:Property>
```

=

```
<rdf:Description rdf:ID=" triggeredBy ">
      <rdf:type rdf:resource="http://www.w3.org/1999/02/22-rdf-syntax-ns#Property"/>
      <rdfs:domain rdf:resource="#IR-Range"/>
      <rdfs:range rdf:resource="#MotionSensors"/>
</rdf:Description>
```



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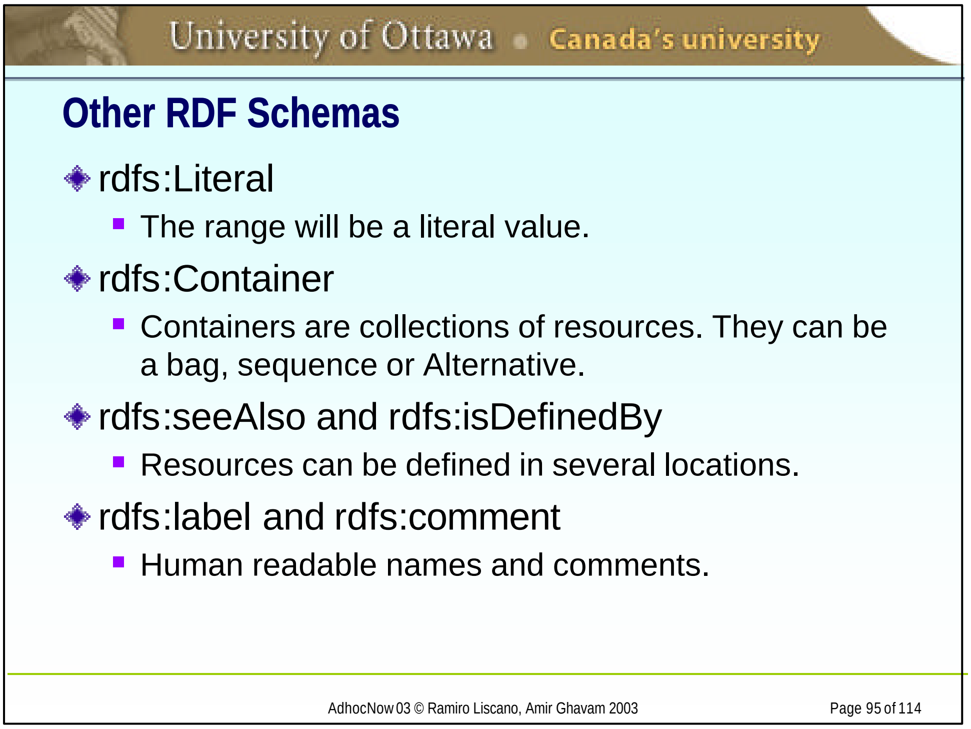
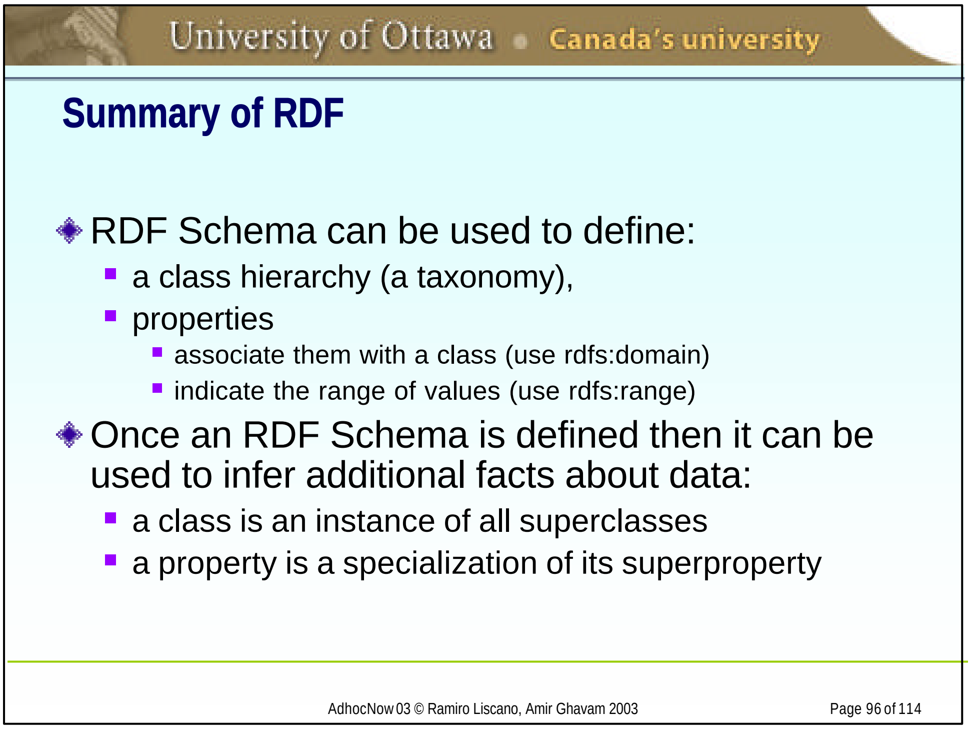
Classes and Properties are Defined Separately

- In RDF you define a class and separately define any relationships to other classes.
- You can define any number of properties and a property may belong to several domains.
- The advantage of this approach is that anyone, anywhere, anytime can create a property and state that it is usable with the class



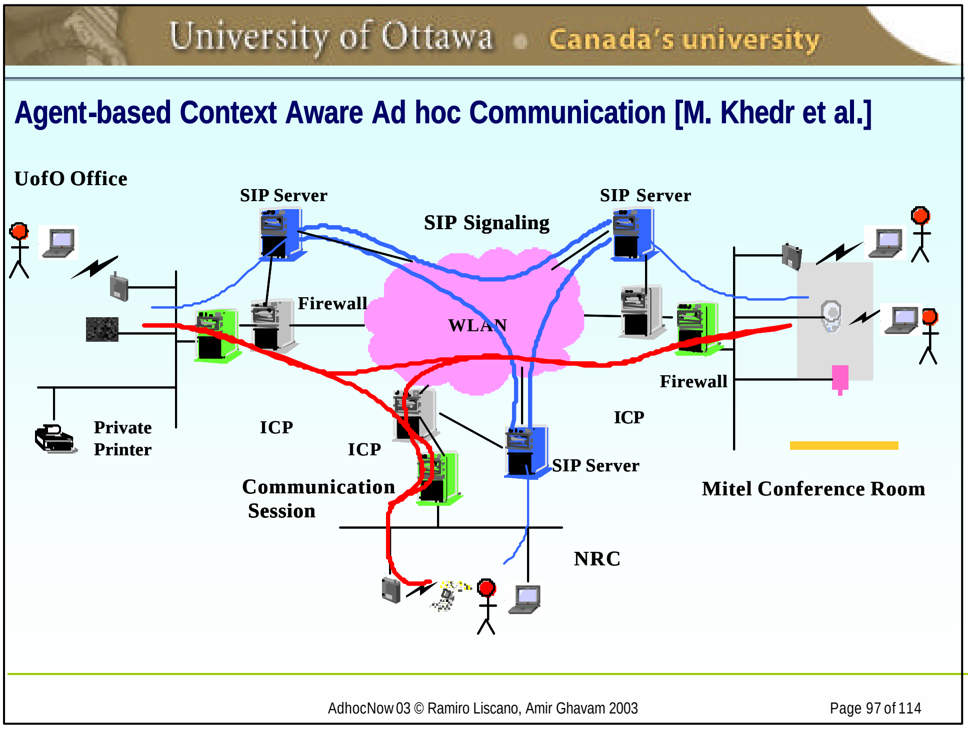
Other RDF Schemas

- rdfs:Literal
  - The range will be a literal value.
- rdfs:Container
  - Containers are collections of resources. They can be a bag, sequence or Alternative.
- rdfs:seeAlso and rdfs:isDefinedBy
  - Resources can be defined in several locations.
- rdfs:label and rdfs:comment
  - Human readable names and comments.



Summary of RDF

- RDF Schema can be used to define:
  - a class hierarchy (a taxonomy),
  - properties
    - associate them with a class (use rdfs:domain)
    - indicate the range of values (use rdfs:range)
- Once an RDF Schema is defined then it can be used to infer additional facts about data:
  - a class is an instance of all superclasses
  - a property is a specialization of its superproperty



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Agent-based Context Aware Ad hoc Communication [M. Khedr et al.]

UofO Office

SIP Server

SIP Signaling

SIP Server

Firewall

WLAN

Firewall

Private
Printer

ICP

ICP

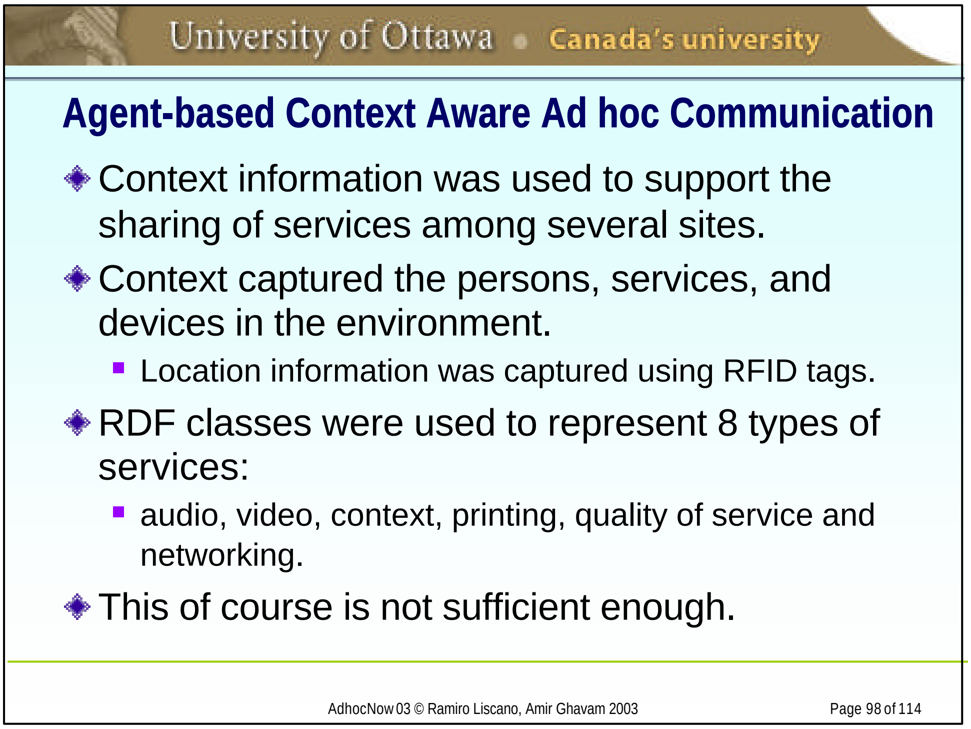
ICP

SIP Server

Communication
Session

Mitel Conference Room

NRC



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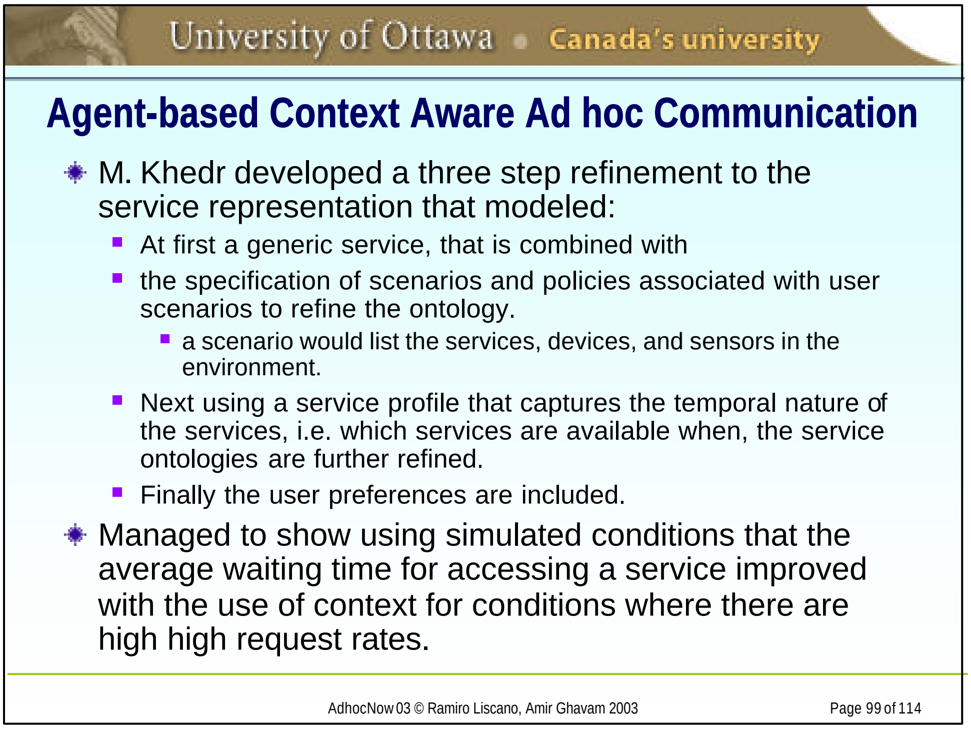
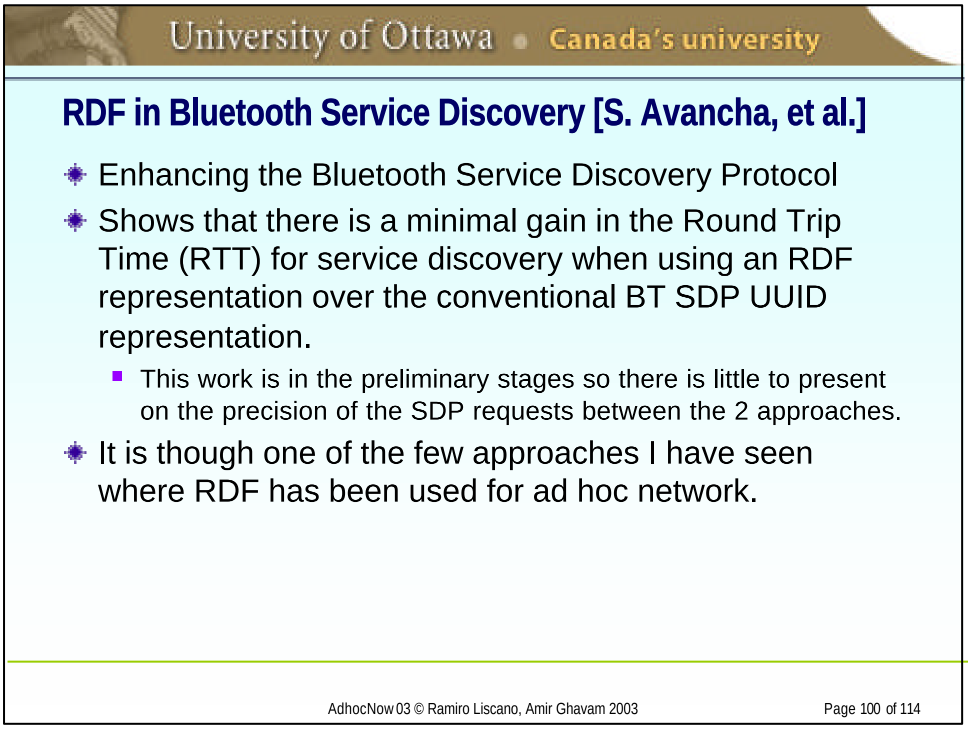
Agent-based Context Aware Ad hoc Communication

- Context information was used to support the sharing of services among several sites.
- Context captured the persons, services, and devices in the environment.
  - Location information was captured using RFID tags.
- RDF classes were used to represent 8 types of services:
  - audio, video, context, printing, quality of service and networking.
- This of course is not sufficient enough.



Agent-based Context Aware Ad hoc Communication

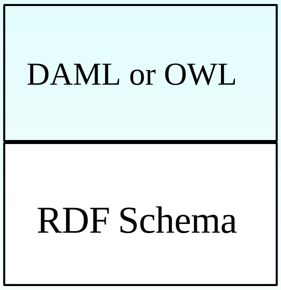
- M. Khedr developed a three step refinement to the service representation that modeled:
  - At first a generic service, that is combined with
  - the specification of scenarios and policies associated with user scenarios to refine the ontology.
    - a scenario would list the services, devices, and sensors in the environment.
  - Next using a service profile that captures the temporal nature of the services, i.e. which services are available when, the service ontologies are further refined.
  - Finally the user preferences are included.
- Managed to show using simulated conditions that the average waiting time for accessing a service improved with the use of context for conditions where there are high high request rates.



RDF in Bluetooth Service Discovery [S. Avancha, et al.]

- Enhancing the Bluetooth Service Discovery Protocol
- Shows that there is a minimal gain in the Round Trip Time (RTT) for service discovery when using an RDF representation over the conventional BT SDP UUID representation.
  - This work is in the preliminary stages so there is little to present on the precision of the SDP requests between the 2 approaches.
- It is though one of the few approaches I have seen where RDF has been used for ad hoc network.

RDF as a Building block for Semantic Languages

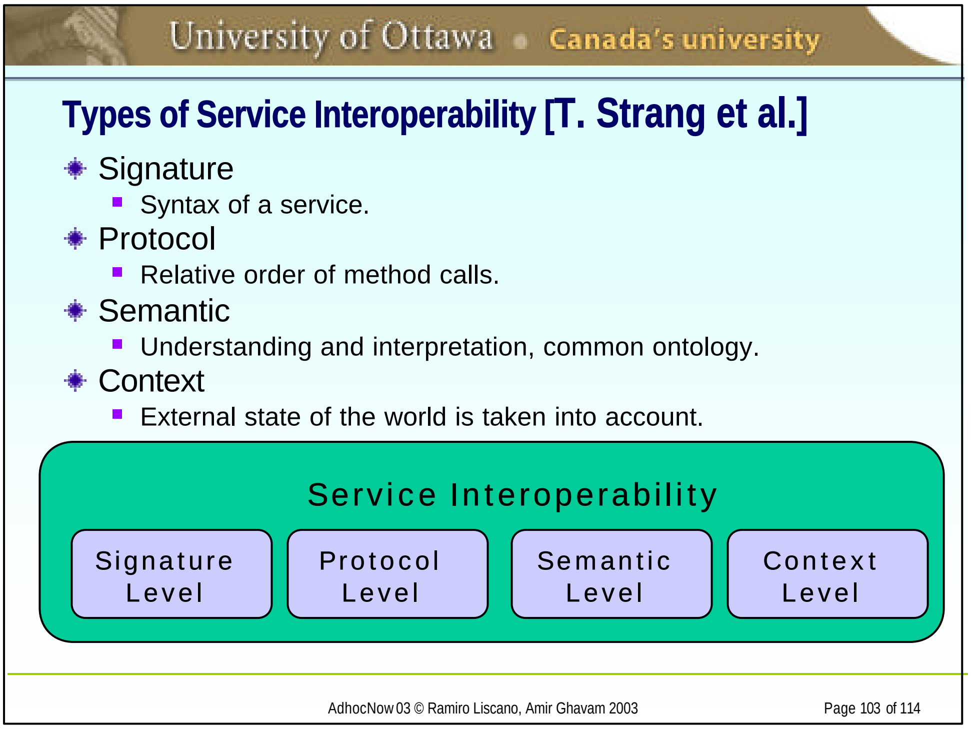


OWL = Web Ontology Language - see the OWL Tutorial at: http://www.xfront.com/owl/

DAML = DARPA Agent Markup Language - see the DARPA Tutorial at: http://www.xfront.com/owl/

RDF Schema was designed to be extended. The ontology languages all use RDF Schema's basic notions of Class, Property, domain, and range.

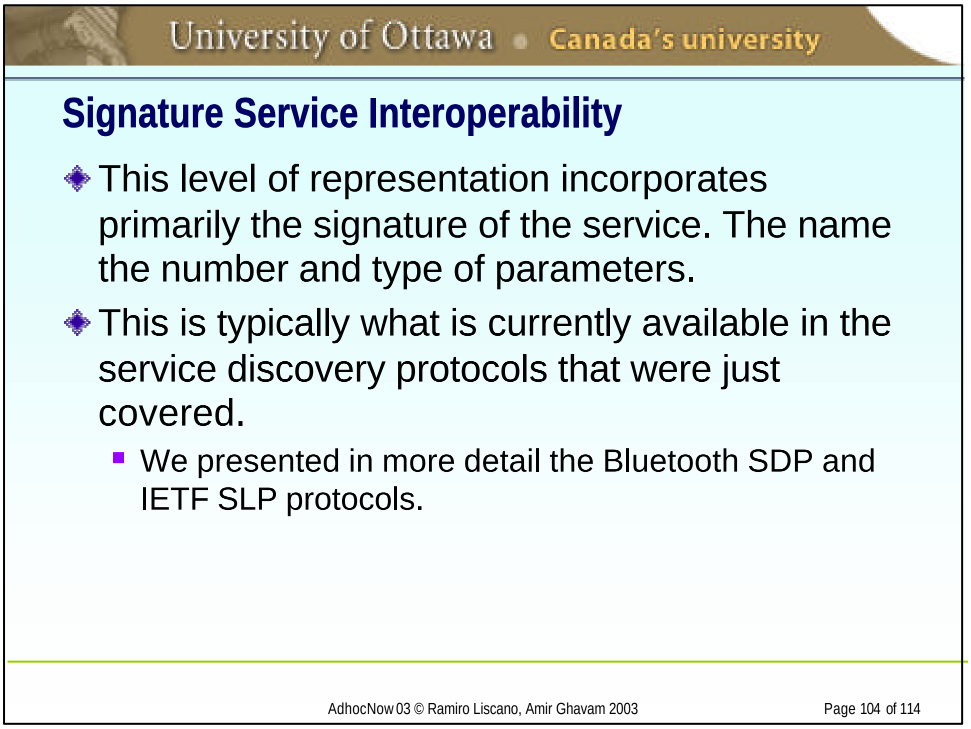
Summary



Types of Service Interoperability [T. Strang et al.]

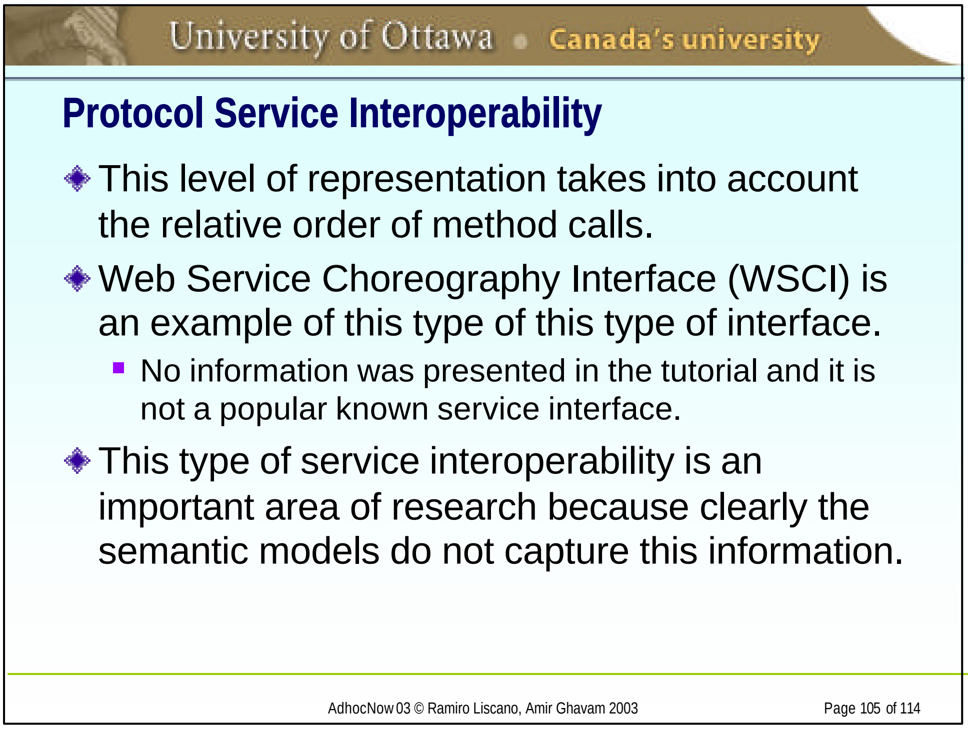
- Signature
  - Syntax of a service.
- Protocol
  - Relative order of method calls.
- Semantic
  - Understanding and interpretation, common ontology.
- Context
  - External state of the world is taken into account.

Service Interoperability
Signature Level
Protocol Level
Semantic Level
Context Level



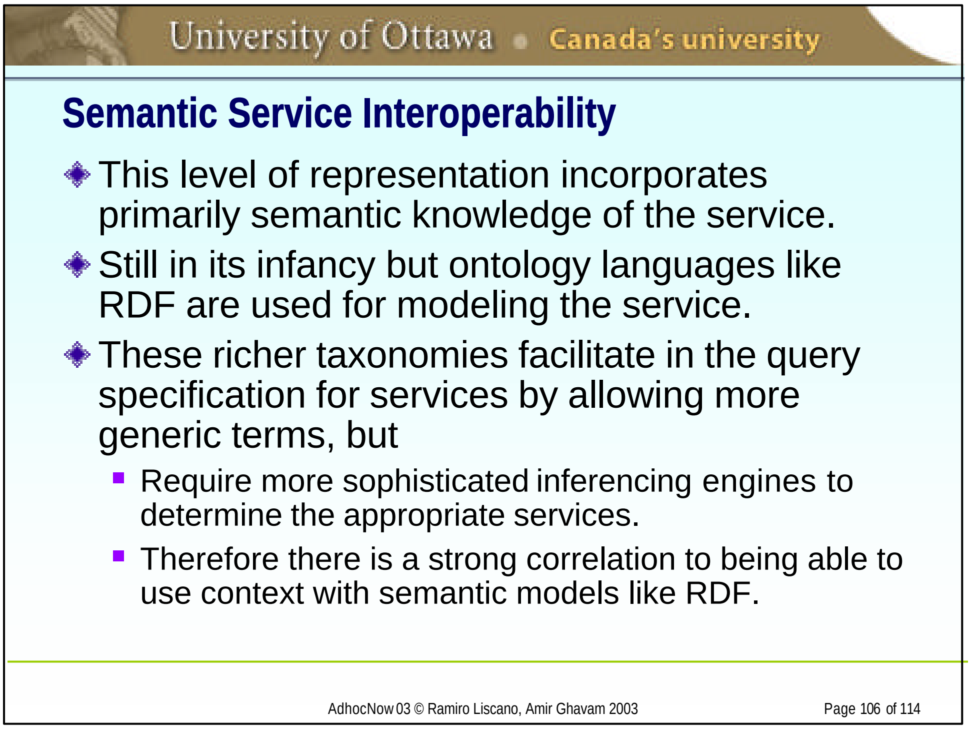
Signature Service Interoperability

- This level of representation incorporates primarily the signature of the service. The name the number and type of parameters.
- This is typically what is currently available in the service discovery protocols that were just covered.
  - We presented in more detail the Bluetooth SDP and IETF SLP protocols.



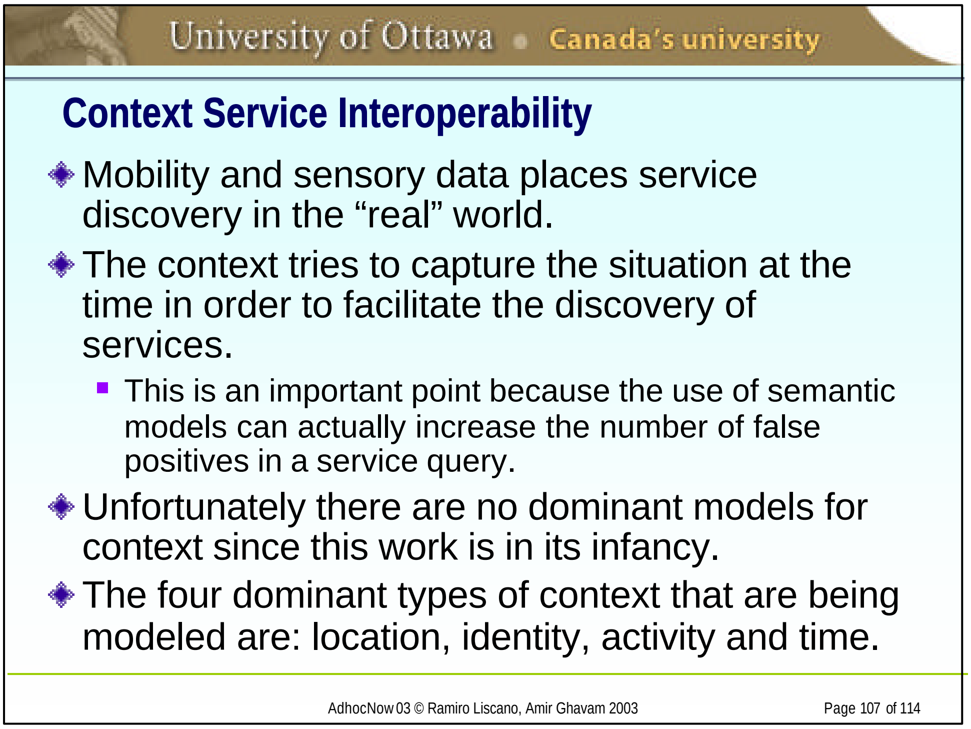
Protocol Service Interoperability

- This level of representation takes into account the relative order of method calls.
- Web Service Choreography Interface (WSCI) is an example of this type of this type of interface.
  - No information was presented in the tutorial and it is not a popular known service interface.
- This type of service interoperability is an important area of research because clearly the semantic models do not capture this information.



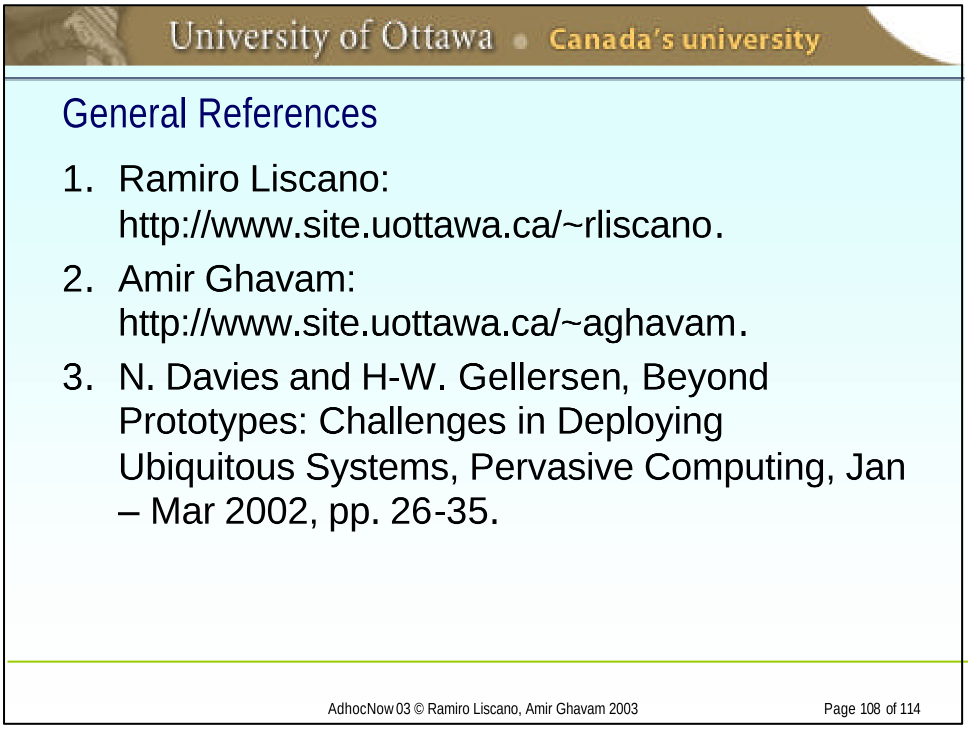
Semantic Service Interoperability

- This level of representation incorporates primarily semantic knowledge of the service.
- Still in its infancy but ontology languages like RDF are used for modeling the service.
- These richer taxonomies facilitate in the query specification for services by allowing more generic terms, but
  - Require more sophisticated inferencing engines to determine the appropriate services.
  - Therefore there is a strong correlation to being able to use context with semantic models like RDF.



Context Service Interoperability

- Mobility and sensory data places service discovery in the "real" world.
- The context tries to capture the situation at the time in order to facilitate the discovery of services.
  - This is an important point because the use of semantic models can actually increase the number of false positives in a service query.
- Unfortunately there are no dominant models for context since this work is in its infancy.
- The four dominant types of context that are being modeled are: location, identity, activity and time.



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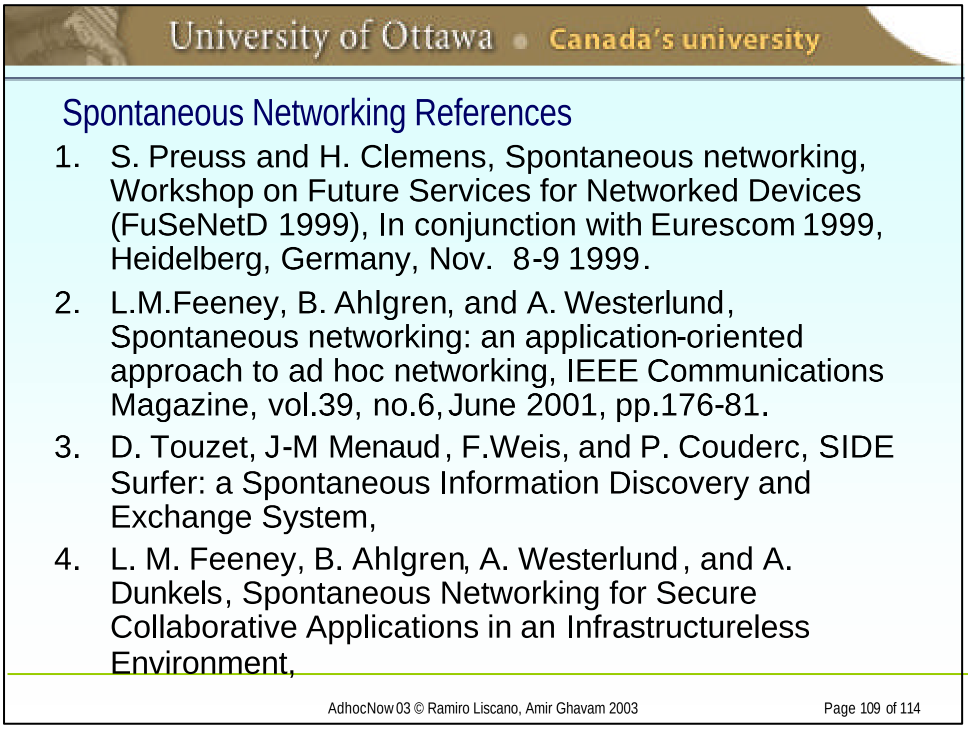

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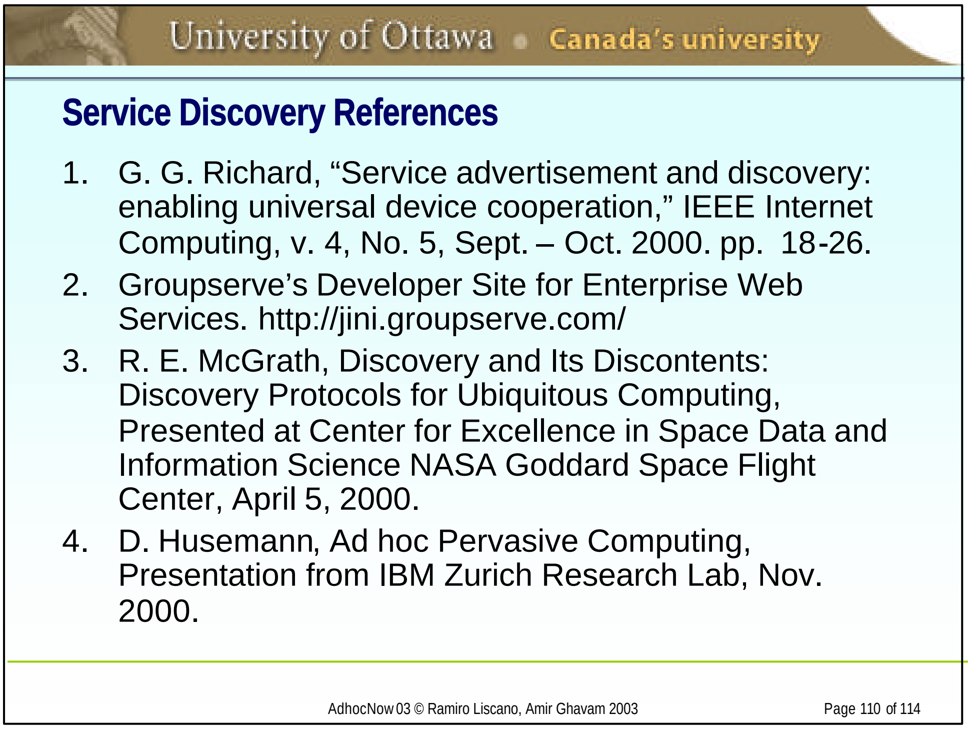

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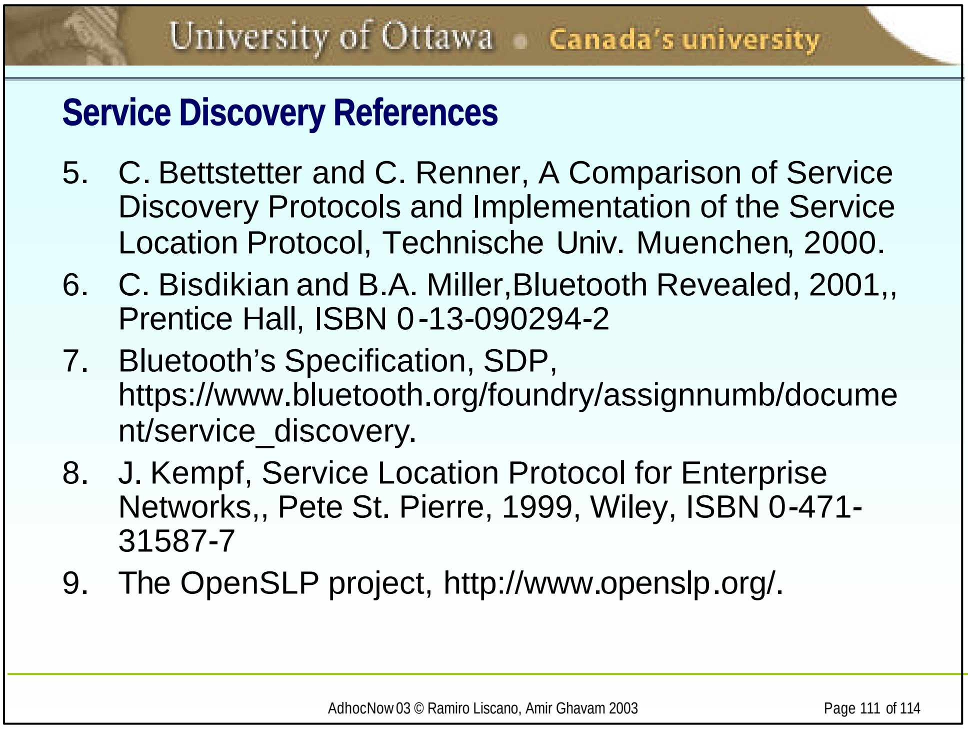

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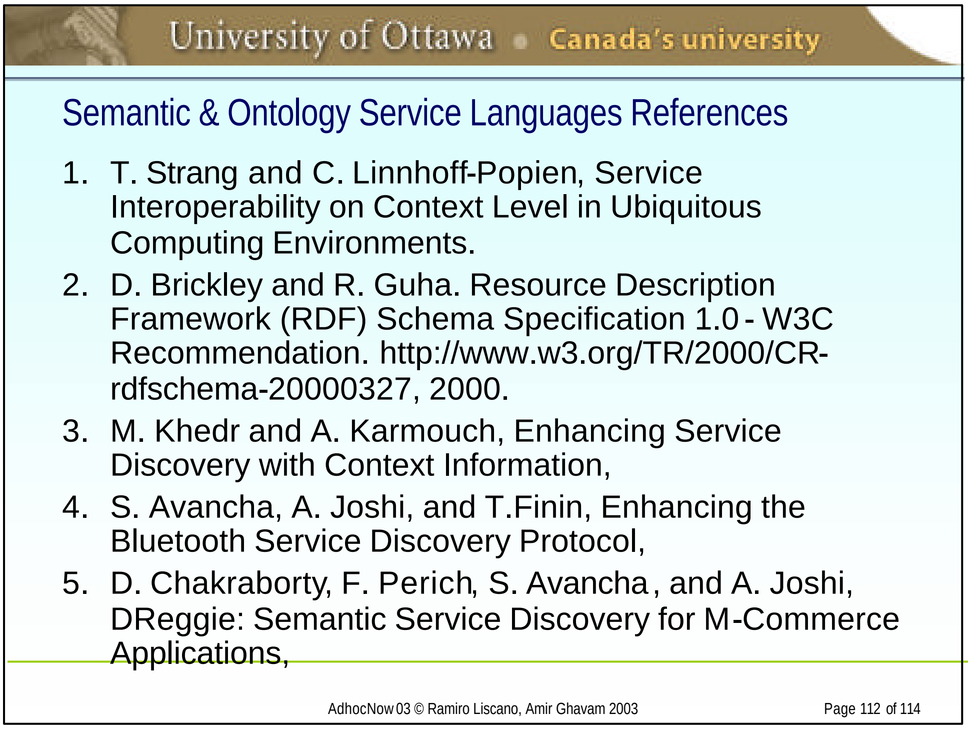

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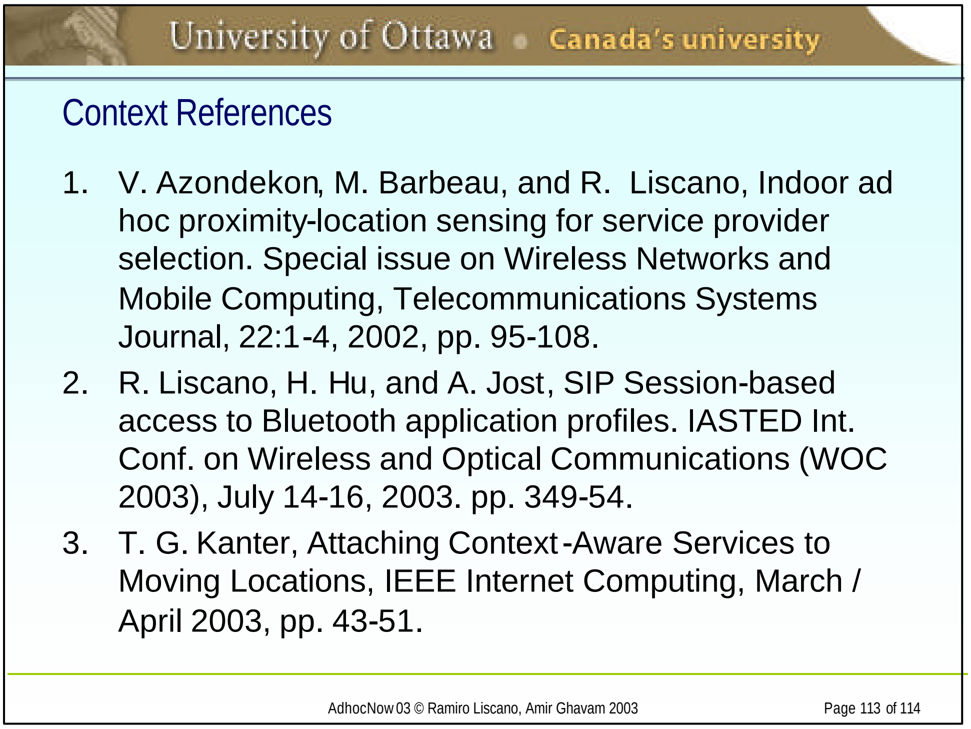

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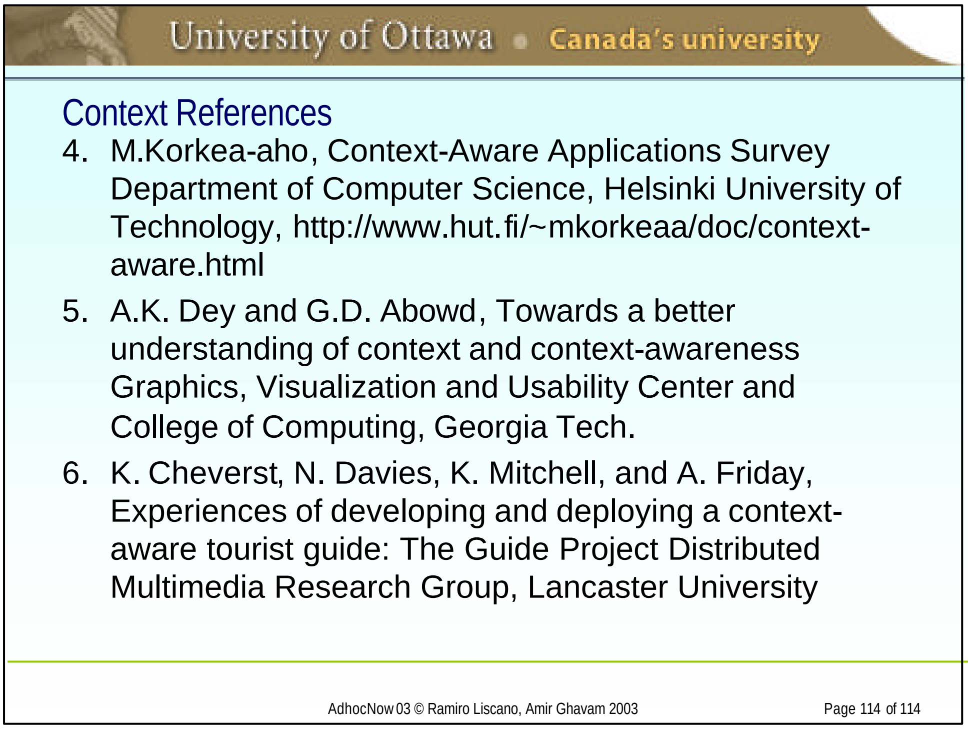

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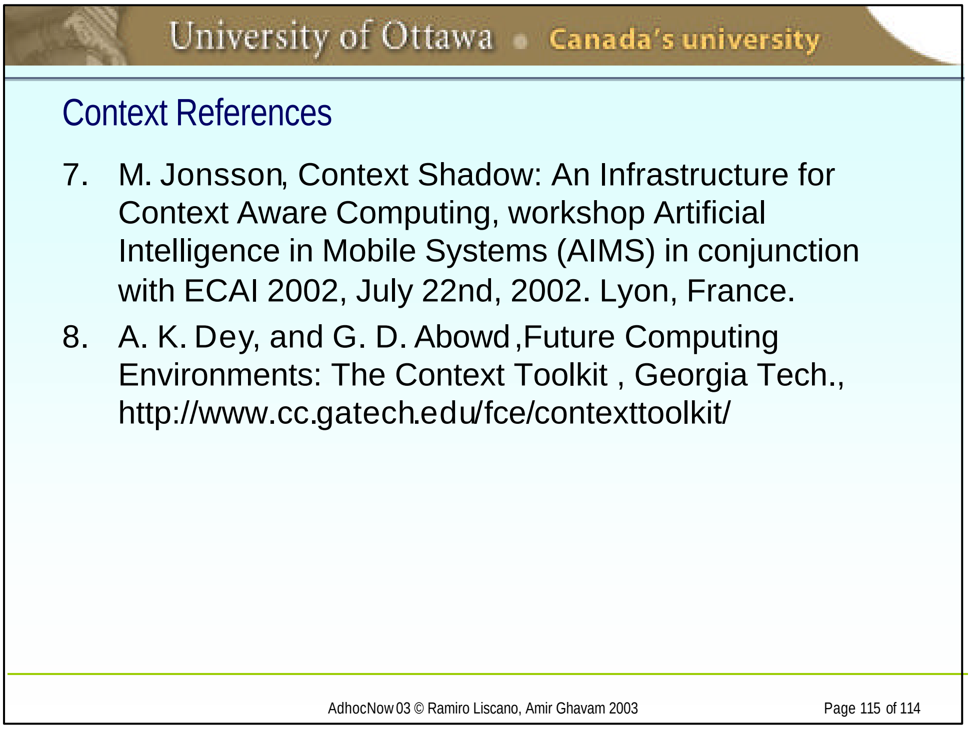

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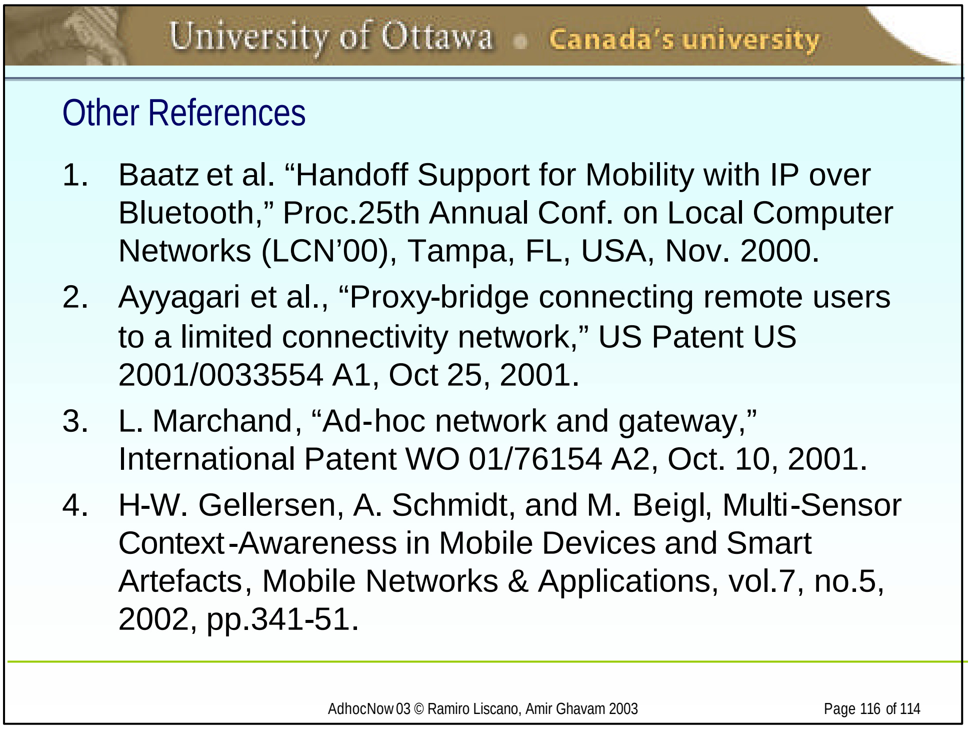

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