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# Sensor Profile Requirements for Sensor Network Capability Information in the EPCglobal Network

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# Abstract

In this paper we discuss requirements for supporting sensor network capability information in the EPCglobal Network. Due to increased functional complexities sensor network capability information will be an essential part in the future EPCglobal Network. We propose sensor profile service that stores sensor network capability information, called sensor profile, in distributed servers on the Internet and allows users or networked clients to effectively retrieve them using EPCs of target sensor nodes.

# 1. Introduction

## 1.1 Sensor Integration in EPCglobal Network

The EPCglobal Network [2], often called "The Internet of Things [1]", allows computers to automatically recognize and identify goods in the supply chain with radio frequency identification and to share related data over the Internet [11][12]. However, there is no way to sense physical environments and to know precise conditions of the identified objects with current EPCglobal Network.

For the reasons small, low cost, low power wireless sensor networks have been paid attentions to capture physical environments and to process sensory information in a variety of application fields. Wireless sensor networks enable physical status sensing without established infrastructures such as power line or wired networked connections. In addition, self-configurable software and distributed processing in wireless sensor networks make them to be attractive solutions for physical environmental sensing.

However, wireless sensor networks do not have global standards like EPCglobal Network, and they are naturally application dependent rather than applicable for general tasking. Established sensor networks are developed as isolated system without Internet connectivity or a standard data sharing architecture.

Integration of wireless sensor networks with standardized EPCglobal Network enables precise status monitoring of identified objects and to share sensing/identification information between multiple participants via standardized interfaces. Real benefits of WSNs will be achieved when end users with appropriate authority can access sensing data using standard based internet interfaces. Integration of sensors with EPCglobal Network was introduced in early publications [10][13].

## 1.2 Sensor Network Capability Information

Auto-ID center [14][15] and EPCglobal [2] defined a RFID Class Structure to classify tags as belonging to one of five classes: Class 1 (Identity Tags), Class 2 (Higher Functionality Tags), Class 3 (Semi- Passive Tags), Class 4 (Active AdHoc Tags), or Class 5 (Reader Tags). Each successive class within this framework builds upon, i.e., is a superset of the functionality contained within, the previous class, resulting in a layered functional classification structure.

Sensor networks that have sensing and processing capabilities, battery, and ad-hoc communication are the best matched with RFID class 4 active tags, but actual functions and capabilities offered by sensor networks are varied according to target tasking and deployment environments.

Capabilities of basic Class 1 Tags were not as important as one of wireless sensor networks because they are commonly used for simple identification purpose without advanced functionalities or big capability variations. However, tags or sensor nodes classified in higher RFID Class Structure need metadata to describe their heterogeneous capabilities and to allow readers or applications to access them. For the purpose EPCglobal Network standard provides Tag Identification (TID) memory bank encodings for indicating information of capabilities of tags. It is described in EPCglobal architecture framework and tag data standard [2].

*Tag Data Standard defines the encoding of TID memory for Gen2 Tags, which encodes information about the Tag itself as opposed to the object to which the tag is affixed. This information may include the capabilities of the Tag. The examples of such information are how much memory it contains, or whether it implements optional features, etc.) [2].*

With increased complexities and advanced functionalities of sensor networks TID memory needs to cover more encodings for capability information. It will not be used for only indicating existences of user memory and but also for sensor calibrations, message formats, and so on.

Advanced capabilities make TID encoding complex, but resource constraints prohibit sensor nodes to store large size of capability information especially when they are written in XMLs or high level models languages preferred by networked applications. In addition ad-hoc communications in wireless sensor networks make it problematic by spending more energy during transmitting sensor node capability information over multiple intermediate sensor nodes [5].

As results, capability information in sensor networks is a more challenging issue than one used for simple RFID tags and current EPCglobal Network. A question about how to effectively support sensor network capability information within future EPCglobal Network motivates our work.

## 1.3 Capability Information within Global Scale Architecture

Sensor networks are often tightly coupled with particular tasking or individualized GUIs who have prior capability information (i.e., sensor types, available operations, message formats, or hardware/software configurations) to query, configure sensor networks and to interpret sensing data. Since typically wireless sensor networks are developed as application-dependent, isolated, and decentralized in-network processing systems, standardized capability information is needed to change them to general tasking system and to support late bindings between sensor networks and applications over Internet.

Readers or clients can understand and access sensor nodes provided that they have self-describing capability information. However, it is infeasible for readers or clients to have capability information needed to access all types of tags and sensor nodes in advance. Because we aim to design an sensor integrated global scale architecture that would enable organizations over the world to identify things and share physical data collected by wireless sensor networks [11], it is important to make them available without prior knowledge or pre-loaded capability information. The requirement for transparent data collections over heterogeneous sensor networks within global scale architecture is another motivation for our work.

## 1.4 Sensor Integration Architecture Framework

We believe EPCglobal Network provides the underlying infrastructure for an integrated sensor networks. Because current EPCglobal Network is designed to support basic RFID tags (RFID Class Structure tags), we needs to extend it to support wireless sensor networks. These extensions raise all levels of technical issues from sensing data capturing in LLRP and complex sensor event processing in ALE to high level sensor data supports in EPCIS. Importantly, the architecture will support both RFID tags and wireless sensor networks. Figure 1 shows proposed sensor integration architecture.

There are many propriety wireless sensor network solutions and it led some standardization efforts such as ZigBee [4], 6lowpan [16], and Open Geospatial Consortium [23]. However, due to lack of globally dominant standards sensor networks cannot communicate with other sensor networks or network architecture.

To provide capabilities information, which we call sensor profile, we adopt EPC (Electronic Product Code) standards in EPCglobal Network. We store sensor profiles in servers on the Internet, and allow networked clients to search or download them using an EPC assigned to each sensor node. To look up authorized sensor profile servers we extend object naming service (ONS) that changes EPCs to authorized locations of EPCIS.

Sensor profile service may used by different subscribers for different purposes. For examples, Readers may use sensor profile to query heterogeneous sensor networks. ALE middleware may depend on sensor profiles to understand high level sensing / event data produced by sensor networks in order to apply various event rules.

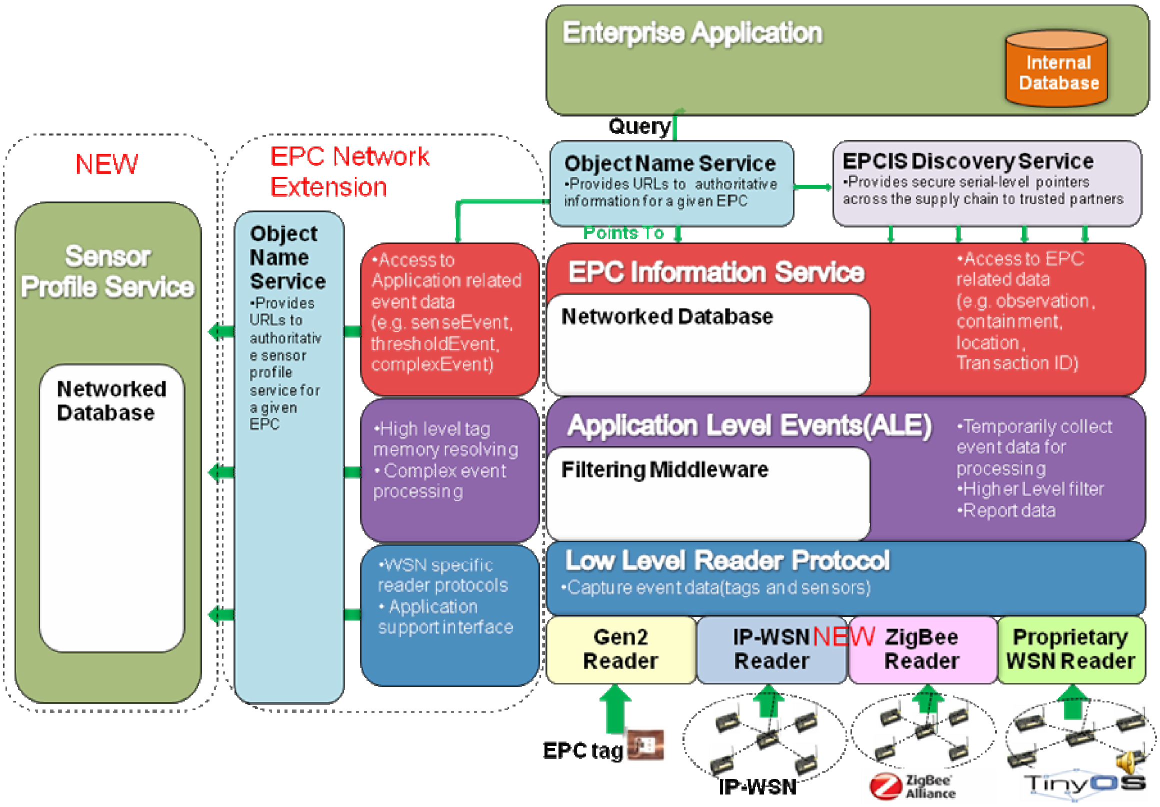


*Figure 1 Sensor Integration in EPCglobal Network*

# 2 Related Work

Dislike Internet computing wireless sensor networks generally pay attentions on collected data itself than identifying particular sensor nodes. This observation lead to data centric communication paradigm that uses attributes and named data to enable in-network processing for wireless sensor networks. Sensing data is named using attribute/value pairs to self-describe sensing data. Intermediate sensor nodes during multi-hop communications can understand data and run in-network processing to eliminate redundancy, to minimize the number of transmissions and to save energy [18][19][20]. However, such named data is limited to considerably simple attributes to fits into application messages. In addition, metadata data used in data centric communication are necessarily applications dependent

Standardizing sensor interfaces has been a popular research issues among research communities. IEEE 1451 standard [3][17] has worked on defining a standard for a networked smart transducer. As a core of smart transducer, the IEEE 1451 standard defined a transducer electronic data sheets (TEDs) and its data format. The Semantic Sensor Web

(SSW) proposes that sensor data annotated with semantic metadata that will both increase interoperability and provide contextual information essential for situational knowledge [23]. Integration of IEEE1451 and OGC-SWE is introduced in [22]. ZigBee [4] defined application profiles as agreements for messages, message format and processing actions for interoperable devices. These works store standard TEDs and profiles in target devices such as transducers or sensor nodes.

However, storing metadata in resource constrained sensor nodes is infeasible in terms of costs. Storing metadata in resource constrained sensor nodes results in increased storage costs and high energy consumptions during transferring them over error prone wireless networks. It becomes a more serious problem when sensor metadata is transferred via multi-hop communications which involve a number of intermediate sensor nodes in routing paths with. It consequently leads to high energy consumptions in wireless sensor networks which takes energy for the most important performance factors. This problem was presented in [5]. In tiny sensor networks it is also highly restricted to support XMLs or high level models preferred by networked applications or users. If capability information is written in XML description, it would require almost 10 times bigger size than descriptions using custom defined encoding [6].

Auto-ID Lab Keio [7] and Microsoft SenseWeb [8] proposed networked architecture to register and query sensor descriptions, and the IEEE 1451 virtual TED [9] uses a Web-accessible TED database. However, they use centralized repositories which easily suffer from scalability problems or they depend on human web browsing instead of autonomous retrieving of sensor profile or descriptions.

A general device-controller approach in service discovery protocols such as UPnP, consisting of service provider (device) that provides descriptions and service client (controllers) that access them, is not suitable for wireless sensor networks for the same reason. Another approach to leverage capability information in wireless sensor networks is using application level gateways that act as proxy and respond to clients' requests on behalf of sensor nodes [21]. With this architecture base stations can provide descriptions while each sensor node is hidden from outside networked clients. However, because this proxy approach results in dependency with the base station, sensor network capability information should be decided and pre-loaded into base stations in advance.

# 3 Design Consideration

There are several challenging points in order to leverage sensor profile in integration of wireless sensor networks and EPCglobal Network. We assume a centralized communication model between sensor nodes and a base station rather than localized communication algorithms between sensor nodes. Thus, our approach is the best suitable when the Internet connected readers or particular roles (i.e., ALE, EPCIS) in EPCglobal Network use sensor profile. In this case, it is advantageous to support sensor profile within networked architecture instead of storing them into tiny sensor nodes and transferring them over multi-hop wireless channels. Sensor profile requirements are summarized below.

- Precise sensor profile

Since profile descriptions are used to replace prior knowledge, they need to be precise enough to cover all information required to understand, access sensor nodes. Although there are some proposed standards for describing capabilities in SensorML [23], IEEE 1451 [3][22], ZigBee [4] and TinyML [26], they are not suitable for our global scale sensor integrated architecture. For example, global location services offered by SensorML [23] rely on characteristics that differ from embedded wireless sensor networks. ZigBee [4] and IEEE 1451 [3][22] are more suitable for intra networks. Sensor profile is different with them in that it does not describe sensing data collected or dynamic information configured during running time. It is necessary to define capability schemes and to incorporate them with sensor integrated network architecture.

- Minimized overhead of sensor networks

Storing and transferring sensor profile written in high level language is burden to resource constrained sensor nodes. It becomes a more serious problem when size of sensor profile increase or there are more intermediate nodes during transmissions as shown in Figure 2. The overhead of sensor profile in multi-hop environments is explained in the paper [5]. Sensor profile descriptions protocol should be designed to minimize overhead of resource constrained wireless sensor nodes.

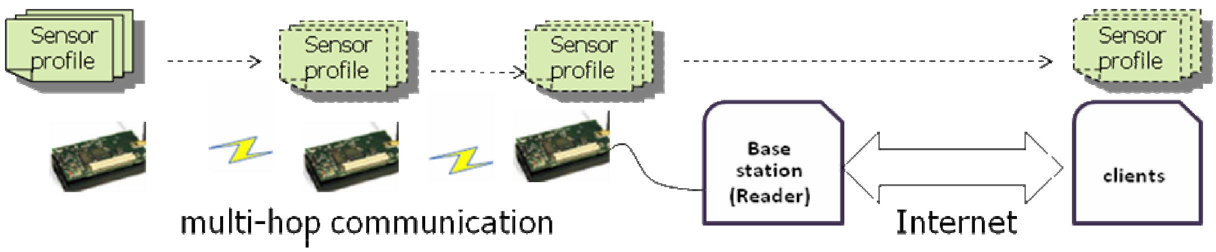


*Figure 2 sensor profile transmission over multi-hop communications*

- Association between sensor node and sensor profile

Instead of locally unique network addresses in wireless sensor networks, we use globally unique identifiers for sensor profile service. To use Electronic product code (EPC) standards in EPCglobal Network an EPC is assigned to each wireless sensor node. Sensor profile stored in Internet servers is logically mapped with an EPC of a desired sensor node. It is worthy to note that these EPCs encode information about the sensor node itself as opposed to information about objects to which the typical RFID tags are affixed in standard EPCglobal Network. We use an EPC based sensor profile as extension of TID memory.

- Autonomous sensor profile look up

Because sensor profiles are scattered across the distributed servers, appropriate locations for desired sensor profile descriptions needs to be resolved. Centralized profile descriptions servers cannot scale well and resolving mechanisms are needed to enable autonomous lookup processes without human involvements. We simply extend the object name service (ONS) for resolving locations of authoritative sensor profile servers for given EPCs in addition to locations of EPCIS in standard EPCglobal Network.

# 4 Comparison between Sensor Profile and EPCIS Event Data

EPCglobal Network deals in two kinds of data, called event data and master data, in EPC Information Service (EPCIS). They are different with sensor profile in that they are information about objects that affixed tags represent. For an example, with sensor node attached pallets event data will be information explaining status of the pallets while sensor profile data will be information about sensor node itself. Thus sensor profile remains unchanged while event data grows as more sensing data or events are detected.

Sensor profile is also different with static master data consisting of standardized vocabularies to explain event data and process logic. Sensor profile is independent of specific application domain knowledge regardless of EPCIS transactions. It is impossible for EPCglobal subscribers to have capability information about all types of heterogeneous sensor nodes in advance to prepare potential access. If they have to be pre-loaded into EPCIS, new sensor nodes that haven't been seen before or haven't planned in advance cannot be used. Thus our design choice is that sensor profiles are basically maintained by manufacturers, and retrieved by requiring EPCglobal subscribers.

Conceptually it is similar with software drivers that users download from manufacturer websites when installing new hardware. However, noticeably the whole sensor profile retrieving processes need to be done in autonomous ways without human involvements.

Differences between EPCIS data and sensor profile are summarized in Table 1.

***Table 1 comparison between EPCIS data and sensor profile***

| | EPCIS data | Sensor Profile |
|---|---|---|
| Definition | Event data and master data | Sensor network capabilities |
| Feature | Dynamic (event data), static (master data) | Static |
| Clients | EPCIS accessing client | Possibly more broad (Reader, ALE middleware, EPCIS) |
| Interface | EPCIS capture interface / query interface | New query interface(search, retrieving) |
| Resolving | ONS Lookup | ONS Lookup (extension) |
| Schema | Dependent to supply chains (vocabulary) | Independent to specific industries |
| Relationship with EPCglobal Network | Specific | Independent (applicable for sensor networks without standard EPCglobal Network) |
| Manager | EPC subscribers | Manufacturers or subscribers |

# 5 Sensor Profile Service

Our approach is to store sensor profile in servers on the Internet, and allow networked clients to search or download relevant profile using an EPC of target sensor node. To identify sensor nodes we assign EPCs to sensor nodes. To find authorized sensor profile servers, called sensor profile server, we adopt resolution service by extending ONS that changes an EPC to authorized locations of EPCIS. Readers or other roles in EPCglobal Network who do not have prior capability information but want to access sensor networks and physical data collected from them may use sensor profile services.

Compared to normal sensor networks sensor nodes need to have at least one globally unique EPC to uniquely identify them, and both queries/reports are used based on its unique EPC. As an example, extended versions of LLRP in EPCglobal Network can specify an EPC to filter and query sensor nodes. The performance of EPC based queries/responses will be important points, but they will be addressed in future works. We depict the architecture and interfaces for sensor profile service when F&C in EPCglobal Network is used as a client to retrieve sensor profile.

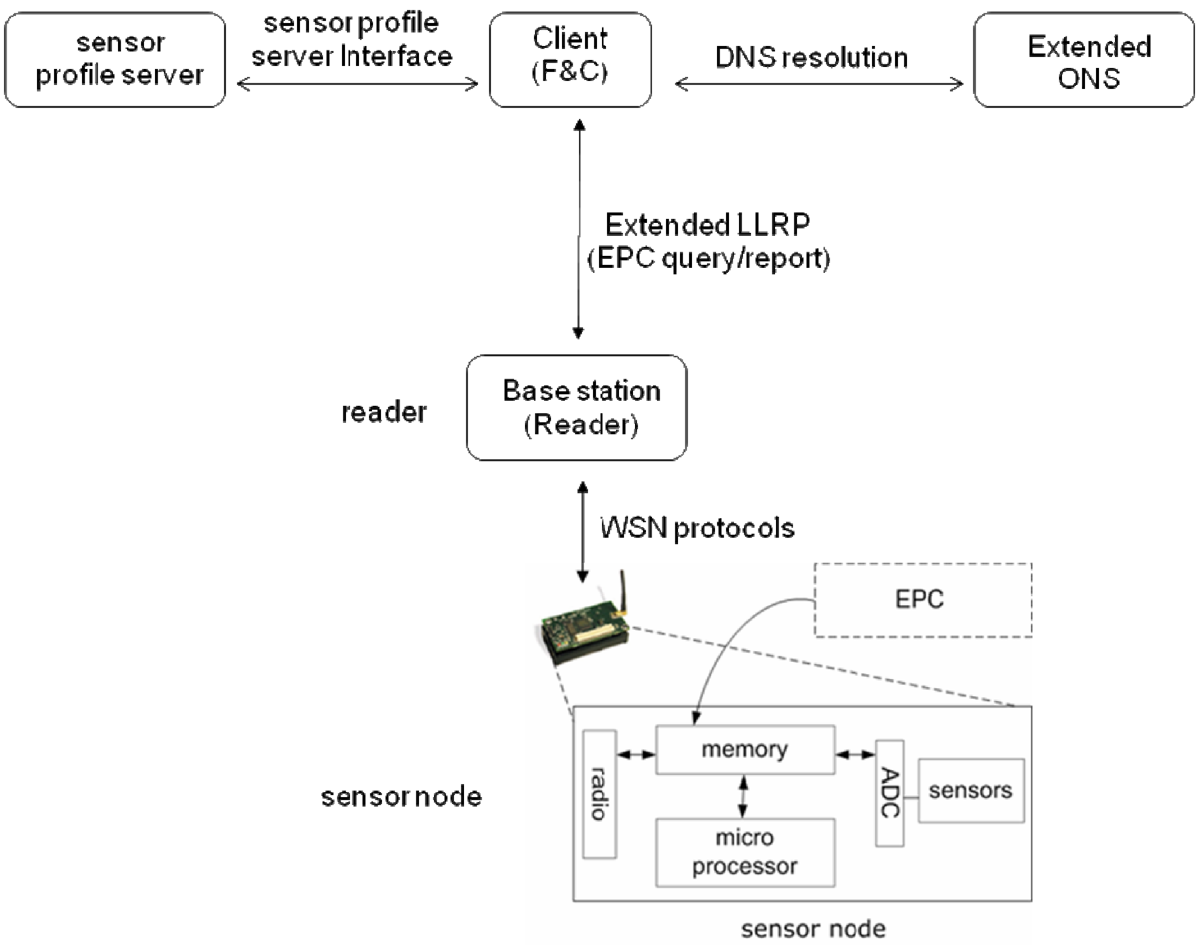


*Figure 3 Sensor Profile Service*

## 5.1 Sensor Profile Classification

We define a sensor profile as static, self-describing information for explaining sensor node capabilities [5]. Dynamic information, on the other hands, changes continuously according to sensor node status, and we exclude them in sensor profile. For several reasons static information and dynamic information need to be considered separately. Some typical examples of dynamic information are deployed locations, duty cycle, and battery level. Dealing with them in sensor profile consequently requires update mechanisms during running time.

If sensor profile supports dynamic information there might be a synchronization problem when clients read changed sensor profiles. Or if multiple clients (i.e. ALE and Reader) write different values to dynamic attributes (i.e., duty cycle) at the same time, priorities are needed to distinguish requests. Instead we simply assume that dynamic information is directly queried by sensor nodes via extended LLRP or stored in extended EPCIS like other normal sensing data.

Sensor profile is not developed for dynamic management information configured by sensor networks. Although some management protocols can also use sensor profile, but their purposes are not to manage dynamic information, but to simply know sensor network capability information.

The sensor profile consists of four categories; *sensor*, *sensor node*, *sensor data*, and *application*, and each of them is expressed by attributes-value pairs. The *sensor* category describes information required to understand sensors, and the *sensor node* category is used to explain initial hardware and software configurations of sensor nodes. As examples, *sensor node* category includes battery characteristics, energy models, configurable duty cycle range (duty cycle value configured in running time is not stored in sensor profile), network descriptions, and so on.

The *sensor data* category consists of events information and application message formats for interfacing sensor nodes. The event information defines events list, threshold value for certain events, and their descriptions. The application message formats give a list of available query/actuating services or commands to interfacing with sensor nodes. The *Application* category includes some data required to support applications. *Application* category is highly application dependent. A sensor profile classification and typical attribute examples are shown in Table 2.

*Table 2 sensor profile classification*

| Profile descriptions | Example |
|---|---|
| Sensor | Type, sensing unit, range, sensitivity, coefficient, description, sensor manufacturer, calibration information |
| Sensor node | Sensor list, sensor node manufacturer, hardware description, software and network configuration, location (static), duty cycle information, battery model, |
| Sensor data | Event description, threshold value for each event, application message formats, service operations and input/output parameters |
| Application | Image, icon, pictures, presentation information |

## 5.2 Profile Service Interfaces

Distributed sensor profile servers on the Internet maintain sensor profiles and allow clients to query relevant sensor profile with corresponding EPCs of desired sensor nodes. Sensor profile servers need to pre-defined interfaces for clients to download relevant sensor profiles and to search sensor profiles for specified attributes. To the simplest case sensor profile servers are easily implemented using standard HTTP servers and REST architecture. However, standard web service interfaces will enable operations with better flexibilities if further operations are defined. Updating sensor profile[1] or searching sensor profile will be optionally provided. In Table 3 we show SimpleProfileQuery interface for the illustration purpose.

**SimpleProfileQuery**: The parameters for this query are as follows.

[1] It does not mean changing values of dynamic information. It is the case that manufacturer updates whole or parts of sensor profile.

Table 3 SimpleProfileQuery

| Parameter Name | Value Type | Required | Meaning |
|---|---|---|---|
| QueryName | String | Yes | This is the only one compulsory parameter. It specifies a name of query. |
| EPC | List of String | No | A list of EPCs to query profile data. |
| profileType | List of String | No | If specified, the results will only include profiles whose categories are matched in Parameter Name. Possible values:<br>Sensors,<br>Sensor Nodes,<br>Sensor Data, or<br>Application.<br>If omitted, all data for values are considered. |
| OrderBy | String | No | If specified, the results are ordered according to OrderDirection fileds. |
| OrderDirection | String | No | Possible values are:<br>ASC (ascending order) or DESC (descending order) of EPCs |

## 5.3 Lookup Sensor Profile Server

EPC Manager is “managing authority” for the EPCs in the block, and is the manufacturer of a product in many general cases. Since we assign one EPC into each sensor node for sensor profile different EPC managers may exist for EPCIS and sensor profile. Optionally, they are used to resolve both locations of EPCIS and sensor profile servers if they are under controls of an identical manager.

The Object Name Service (ONS) standard is domain name system (DNS) based resolution system in standard EPCglobal Network to locate authoritative data and services associated with a given electronic product code (EPC) [24][25]. An ONS query to locate an EPCIS server for an EPC would returns the pointers of the several servers storing information on the associated object. In standard ONS operations, returned addresses from hierarchical object name servers are location of EPCIS which stores event data of EPC attached assets. We propose simple ONS extension to return locations of sensor profile servers. This enables users or clients in EPCglobal Network to find and access both EPCIS and sensor profile servers if EPCs are known. Because EPC is used to resolve sensor profile in the identical manner used for resolving EPCIS, it makes overall architecture simple and straightforward.

The results of ONS queries are in the form of NAPTR records which contain several fields for denoting protocols, services and features. Current ONS specification has four registered services in query results: epcis, ws, html, and xmlrpc [25]. Sensor profile needs additional service registration to distinguish sensor profile servers with other services.

*Table 4 ONS response (new registration)*

| Order | Pref | Flags | Service | Regexp |
|---|---|---|---|---|
| 0 | 2 | U | EPC+ws | !^.*$!http://example.com/widget.wsdl! |
| 0 | 1 | U | EPC+profile | !^.*$!http:// example.com/profile.php! |
| 0 | 3 | U | EPC+html | !^.*$!http:// example.com/things.asp! |
| 0 | 4 | U | EPC+xmlrpc | !^.*$!http:// example.com/example.com! |

# 6 Conclusion

Integration of wireless sensor networks with standardized EPCglobal Network enables precise status monitoring of identified objects and to share sensing/identification information between multiple participants via standardized interfaces. Capability information will be essential in the future sensor integrated global scale architecture that would enable organizations over the world to identify things and to share physical data collected by wireless sensor networks because it is impossible for clients to have capability information about all types of heterogeneous sensor nodes in advance.

In this paper we explained sensor profile requirements for sensor network capability information in EPCglobal Network. We stored sensor profiles in distributed sensor profile servers on the Internet and allow users or networked clients to effectively retrieve them using EPCs of target sensor nodes.

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