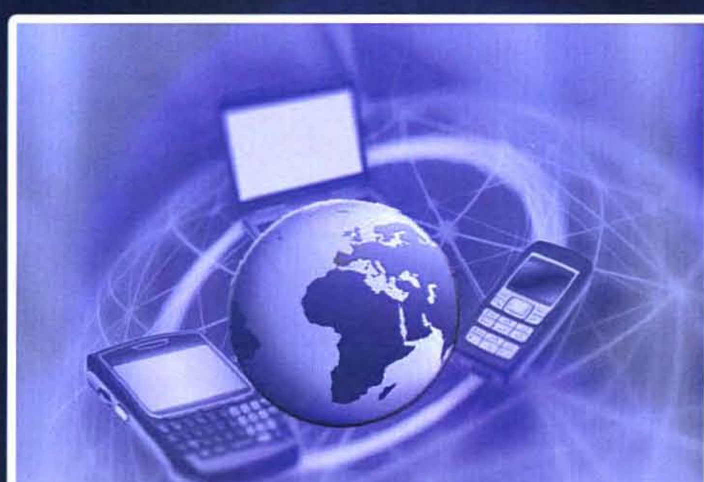
Research Issues in Wireless

Communications and Networking

Farhat Anwar
Wajdi Al-Khateeb



IIUM Press
INTERNATIONAL ISLAMIC UNIVERSITY MALAYSIA

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IIUM Press

Published by:
IIUM Press
International Islamic University Malaysia

First Edition, 2011

Perpustakaan Negara Malaysia Cataloguing-in-Publication Data

Farhat Anwar & Wajdi Al-Khateeb: Research Issues in Wireless Communications Networking

ISBN: 978-967-418-149-9

Member of Majlis Penerbitan Ilmiah Malaysia – MAPIM
(Malaysian Scholarly Publishing Council)

Printed by:
IIUM PRINTING SDN.BHD.
No. 1, Jalan Industri Batu Caves 1/3
Taman Perindustrian Batu Caves
Batu Caves Centre Point
68100 Batu Caves
Selangor Darul Ehsan
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CHAPTER 22

Feasibility Analysis of Integrated Hybrid Systems of Wireless Sensor Networks and Conventional Networks

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22.1 WIRELESS SENSOR NETWORK INTEGRATION WITH CONVENTIONAL NETWORKS

WSN integration can be conceptually defined as the seamless and coherent integration of WSN with other (existing) networks e.g. Internet or 3G mobile networks, etc. WSN is an excellent source of ambient information. The ambient information considered as physical context contains bulk of contextual data (e.g. temperature, location, humidity etc). However, the challenge is how such information can be exchanged consistently with existing networks (e.g. IMS or Internet). Moreover, emerging applications and services require ambient information to be available to external network in order to support wide range of services by utilizing ambient information. As shown in pertinent research works in this field, the integration of WSN with existing network may be based on two approaches: one is gateway-based and another one is overlay-based [1, 2]. In a gateway-based approach, every sensor node in WSN has a proprietary interface to relay data to a gateway. The gateway implements different sets of protocol and information mappings in the form of standardized interface (e.g. HTTP, and SIP) accessible to any user or application in an external network. For overlay-based approach, every sensor or some selected sensors in WSN implement a compatible protocol stack (e.g. IP, HTTP, and SIP) of an external network; So that the host in the external network can communicate directly with sensors. The sensor nodes that implement an external network protocol stack are called overlay nodes and form an overlay-network [3]. The subsequent sections detail the evaluation of state-of-the-art hybrid systems with respect to the evaluation criteria.

22.2 EVALUATION CRITERIA

In this section of this chapter, the criteria for the integration of WSNs with IMS are clearly and logically established. This section recommends the following design criteria and these criteria are an improved set of an earlier proposed set of criteria in a research work [3, 4].

- *Criterion 1*: The approach should support all possible WSN sensing capabilities in IMS. The sensing capabilities refer to different types of sensed data (spatial, environmental, and physiological) accessible to IMS services.
- *Criterion 2*: The approach should allow WSN data to be exchanged in a standard IMS format (PIDF) and also support the aggregation of data based on individual or group of sensors (Sugano, Fujimoto, Klyne, Bateman, Carr, Peterson, 2004).
- *Criterion 3*: Support of information management of different types of physical world entities (e.g. persons, places, objects etc.) in IMS. Currently IMS only support user (person) as a subscribed entity. The WSN can provide information related to different user entities e.g. what's the current: location of a 'user A' (person), temperature of a 'corridor' (place), and spot of a 'car' (object) in parking lot.

- *Criterion 4*: Support the standard publish-subscribe scheme (e.g. SIMPLE) to exchange WSN data in IMS. This criterion suggests the preferred way to exchange WSN information is via publication to IMS so that services or application users can have easy access to WSN data.

- *Criterion 5*: Support of standard IMS communication protocols (e.g. SIP) when interacting with IMS network.

22.3. EVALUATION OF STATE-OF-THE-ART HYBRID SYSTEMS

This section highlights the evaluation of existing work related to integration of WSNs with other networks.

22.3.1 IP-Enabled Wireless Sensor Networks

In some research works, it has been pointed out that it is possible to realize the integration of WSN with Internet by enabling an IPv6 stack in sensor nodes. IP-enabled WSN requires implementing an IP stack in different sensor nodes to allow communication with any host in the Internet. It adapts IP networking to WSN by supporting different functionalities like sensor link layer technologies (e.g. IEEE 802.15.4 - Zigbee), auto-configuration of sensors nodes i.e. dynamic IP address assignment, service discovery, and security for encryption, authentication, and data integrity (Mayer and Fritsche, 2006).

This architecture includes a gateway acting as a router (e.g. default gateway) and provides multiple link access technologies (e.g. Zigbee, WLAN, GPRS etc) that enable global connectivity of sensor nodes with Internet hosts. The gateway also assigns IP addresses to different sensor nodes. Fig. 1 shows the network architecture of IP-enabled WSN.

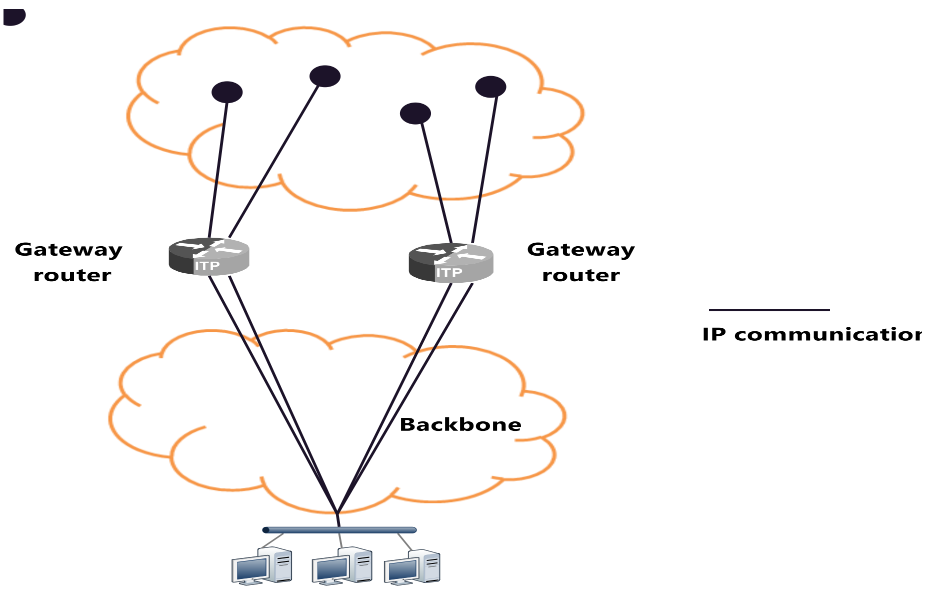


Figure 22.1: IP-Enabled WSN Architecture

Although the approach focused on IP-based integration of WSN with Internet, neither the gateway nor the sensor node provide the standard application interface i.e. which application protocol (e.g. HTTP or SIP) will carry the WSN information. It only supports the sensor-based application software running on top of IPv6 layer i.e. the application directly interfaces with an IP layer. Sensor application software would be a process that collects data from sensors, stores in database while server process reports data to Internet clients. Unlike Internet (TCP/IP) protocols stack, the application layer protocols (e.g. SIP or HTTP) do not interface directly with IP layer so in this case the Internet standard application layer protocol may not be supported. In addition to that there are no such support of different user entities (e.g. persons, places, and objects) and the standard format (PIDF) of information exchange with IMS.

22.3.2 E-Sense Project

The e-Sense provides an architecture that allows WSN ambient information of users and service related objects accessible to B3G mobile networks (Gluhak, Presser, Shelby, Scotton, Schott, Chevillat, 2006). An e-Sense protocol stack was developed for the integration and interworking of WSN and B3G mobile networks as shown in Figure 2. Every node in the WSN either sensor or gateway implements an e-SENSE protocol stack (Gluhak, et. al., 2006). The protocol stack consists of different components to perform different functions. The sensor gateway in WSN provides connectivity to B3G mobile network (Gluhak, et. al., 2006). The components (subsystems) of the protocol stack are as follows:

- *Connectivity Subsystem*: This provides functions performed at physical, MAC, network and transport layer. The Physical layer functions operate the e-SENSE radio transceiver. The MAC layer functions control access to radio channel by using multiple access protocol scheme and reliable transmission of frames. The network layer functions include mechanisms to join and leave network, message routing, security and reliability of message transfer etc.

- *Middleware Subsystem*: This provides functionality for exchanging application related data (WSN data) messages. This subsystem implements publish-subscribe mechanism for data exchange.

- *Management Subsystem*: This performs tasks related to configuration and initialization of connectivity and middleware subsystem. It manages different sensor nodes by defining their roles (e.g. sensor, actuator or sink). With respect to application profiles the management subsystem also provides and implements functions like service discovery, node discovery, security etc.

- *Application Subsystem*: This supports various sensor-based applications that access services provided by middleware subsystem to exchange WSN data between application entities (servers) in B3G mobile network.

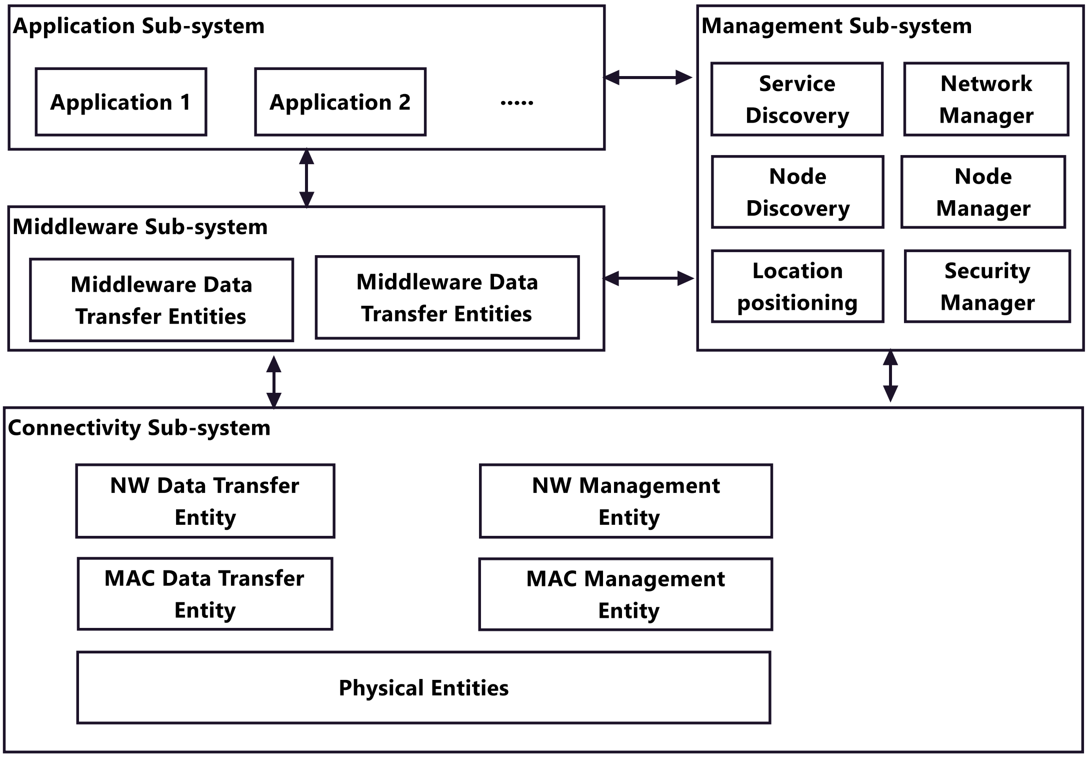
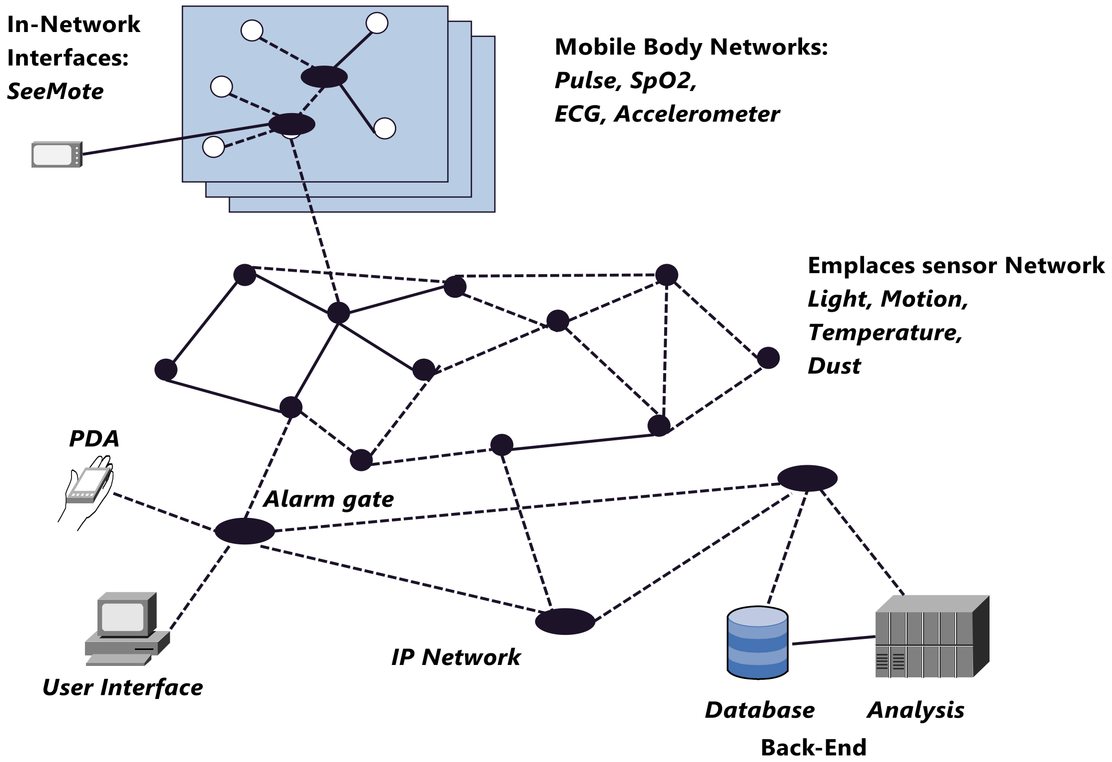


Figure 22.2: E-Sense Protocol Stack

The e-Sense approach provides a service enabling environment that makes WSN ambient information accessible to B3G mobile services. It proposes a possible way to integrate WSN with IMS via Generic User Profile (GUP) (Kauntola, 2007). The GUP is a collection of user related data (e.g. contextual data) stored and manages by UE and the network provider. However the e-Sense did not address issues like support of different user entities (e.g. persons, places, and objects) and the standard format (PIDF) of information exchange.

22.3.3 Alarm-Net

Alarm-Net is a WSN-based health-care monitoring system for assisted living and residential monitoring (Wood, Virone, Doan, Cao, Selavo, Wu, Fang, He, Lin, Stankovic, 2006). It is a heterogeneous architecture that integrates different sensing devices with IP networks. The Alarm-Net supports a query-based protocol for data collection and analysis. It provides different types of sensing capabilities e.g. physiological sensors measure patient's vital sign (e.g. heart rate, blood pressure etc) while physical environment is monitored by environmental sensors. The physiological sensors are attached with patient's body while the environmental sensors are deployed in patient surroundings to monitor patient living environment. The network architecture of Alarm-Net is a hierarchal sensor network consisting of body sensor network (physiological sensors), emplaced sensors are devices deployed in living space to sense environmental quality or conditions (e.g. temperature, dust, motion, light) and AlarmGate (Wireless Sensor Network gateway) as realized in Fig. 22.3. The emplaced sensors communicate with body networks to gather and report data based on user queries. Additionally emplaced sensors communicate with AlarmGate acting as a sensor gateway to

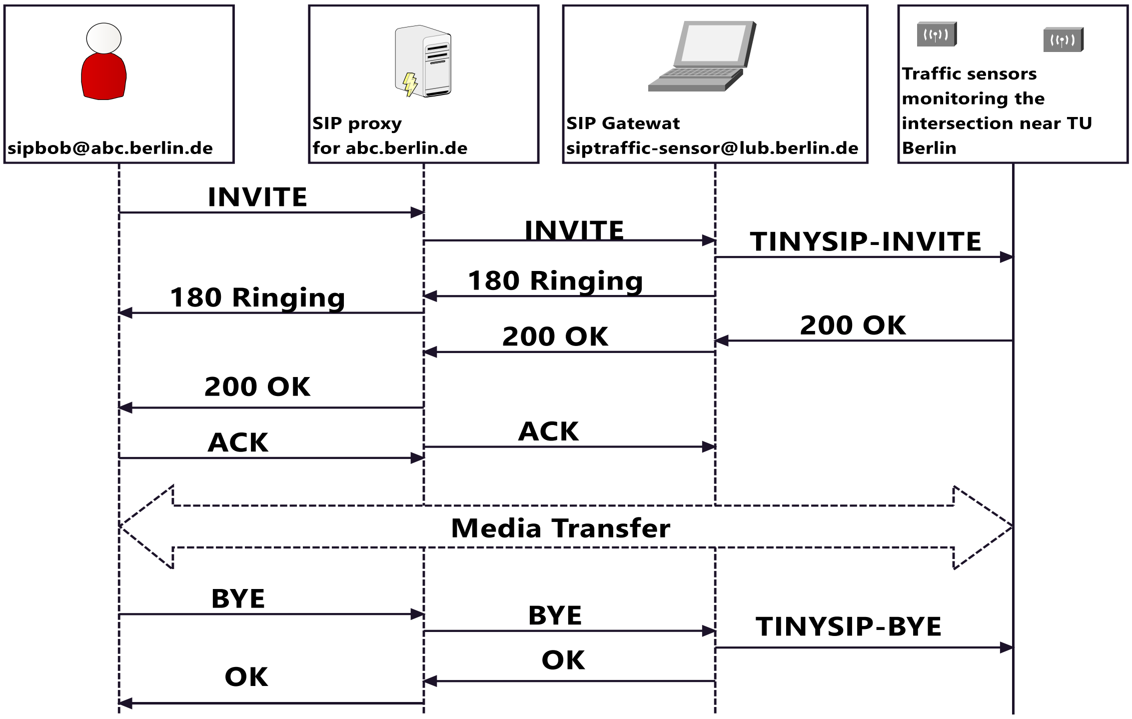


provide sensor data accessible to users (e.g. doctors or nurses). The AlarmGate is similar to an application level gateway between the sensor network and IP network. The gateway host applications to provide aggregation and analysis of sensor data. Each sensor in Alarm-Net implements a query processor stack to facilitate in-network processing of users queries and report the results back to clients. Fig. 22.3 below shows the Alarm-Net network architecture.

This approach supports different WSN sensing capabilities (physiological and environmental). It also provides the aggregation of data from different sensor nodes. It uses a query-based protocol for exchanging WSN data. However the format (PIDF) of information exchange is not standardized and the gateway does not support a standardized application interface (e.g. SIP or HTTP) for querying sensor network.

22.3.4 TinySIP

TinySIP is an another approach that provides a generalized communication platform for accessing sensor-based services from existing wired or wireless networks (Krishnamurthy, 2008). TinySIP is actually based on SIP. Since the sensor nodes are very resource constrained, TinySIP is a light-weight and a subset version of SIP implemented on each sensor node to allow users to access services provided by WSN. In TinySIP, the gateway is

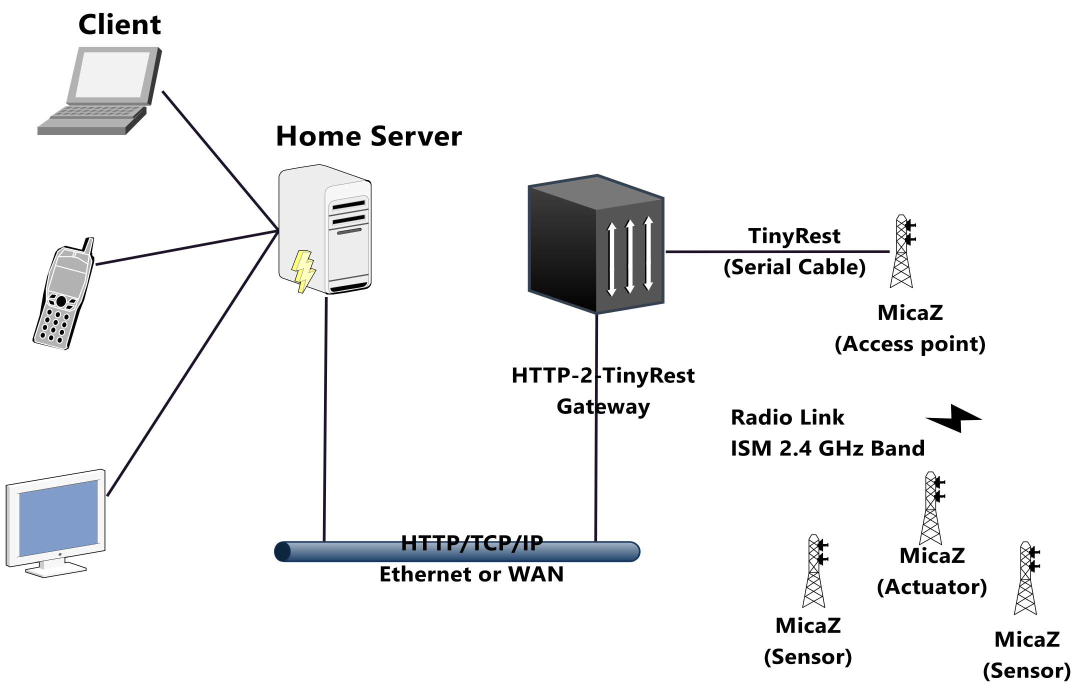


installed to map actual SIP messages to TinySIP messages that are relayed to sensor nodes for processing. TinySIP aims at providing different messaging abstraction to access different WSN services. The messaging abstractions includes: Short Instant Messaging used to configure or perform any task on sensor network. Long session-based messaging is used to establish a session-based communication by sending a SIP INVITE message to one or multiple sensor nodes to collect a large data stream. Publish-subscribe messaging abstraction is based on events i.e. users subscribe to events and get notified of events occurring in WSN. A sensor publishes event data via TINYSIP-PUBLISH request while the gateway sends notifications via NOTIFY request to users subscribed to events. Fig. 22.4 show TinySIP message flow.

TinySIP approach provides a generalized communication platform based on SIP that supports messaging mechanisms that are designed for remotely accessing a sensor network. It supports subset features of SIP and does one-to-one mapping of TinySIP messages with actual SIP messages. However, it lacks support for different types of user entities (persons, places, and objects). In addition to that it does not support the standard format (PIDF) of information exchange as well as the aggregation of sensor data from individual or group of sensors. This approach requires implementing TinySIP protocol on individual sensor nodes considering the fact that sensor nodes in WSN are resource constrained in terms of computation and communication capabilities.

22.3.5 TinyREST

TinyREST is an HTTP-based application level approach to integrate WSN with Internet (Luckenbach, Gober, Arbanowski, 2005). The aim of TinyREST is to support the development of internet-based WSN applications. HTTP is chosen as means for information exchange between sensor network and Internet. The client on Internet issues an HTTP request to access a resource that could be a sensor or actuator. An HTTP request is mapped to TinyOS messages and delivered to sensors. The TinyREST gateway acts as a middleware and performs mapping of HTTP messages to TinyOS messages and vice versa. HTTP requests



supported are: POST used to send commands to control sensors and GET used to collect sensor data. The SUBSCRIBE request is used by the clients to register their interest in specific events and get notifications (NOTIFY) depending on events occurrence. In TinyREST the addressing of sensors is taken care by Home service framework hosted as Home Server which maps sensor or group Ids to locations on location manager. The TinyREST gateway registers with the Home Services Framework (HSF) to receive a HTTP request from clients sent to a particular sensor network.

TinyREST is an application level approach focuses on the integration of sensor networks with Internet that uses an HTTP-based mechanism for information exchange. While in IMS communication among entities (e.g. users and services/applications) is based on a signaling protocol i.e. SIP and HTTP is not a signaling protocol that could be supported in IMS. Besides that TinyREST neither supports the standard format (PIDF) of information exchange nor does it supports different user entities (e.g. persons, places and objects).

22.3.6 3GPP Presence Framework

The 3GPP presence specifies a presence service that provides the user's presence information and possibly the user's context information. The context information can be provided through external sources (e.g. WSN) to entities e.g. watchers or watcher applications in IMS. In presence service an entity that produces a presence information is called presentity, whereas an entity that requests or accesses presence information is called a watcher. A sensor in WSN is a source of contextual information acting as presentity to provide contextual information to presence service. The services and applications in IMS is acting as watcher access contextual information (WSN data) from presence service. The presence service supports a publish-subscribe mechanism for information exchange between presentities and watchers (Howell, 2005).

The presence-based approach seems promising for integration of WSN and IMS. The presence is an integral IMS service that enables the creation of new multimedia services by exploiting the presence (contextual) information. It supports the information exchange in a standard IMS format (PIDF) via SIP messages that is a core signaling protocol of IMS. It possibly support the information related to different entities (e.g. places, objects) proposed in earlier research, and different WSN capabilities (spatial, physiological, environmental) (El Barachi, et. al., 2008).

22.4. EVALUATION SUMMARY

The chart shown in Table 1 provides the evaluation summary of previously discussed approaches. These existing works support some of these criteria for the integration of WSN with IMS. The notations used in evaluation table are: S - Supported, NS - Not Supported, PS - Partially supported.

Table 22.1: Summary of the Evaluation of the Integrated Hybrid Systems

Hybrid Systems	Criteria 1	Criteria 2	Criteria 3	Criteria 4	Criteria 5
IP-Enabled WSN	PS	NS	NS	NS	NS
E-Sense	S	NS	NS	S	S
Alarm-Net	S	PS	NS	NS	NS
TinySIP	PS	NS	NS	S	S
TinyREST	PS	NS	NS	S	NS
3GPP Presence	PS	S	PS	S	S

As it can be seen from the summary above that 3GPP presence could be viable approach towards the integration of WSN and IMS. Although some features are not supported well but through the proper extensions of presence framework different WSN sensing capabilities can be supported in IMS and the support of different user entities (e.g. persons, places, objects).

22.5. CONCLUSION AND RECOMMENDATIONS

The IP multimedia subsystem is a service control architecture for enabling the provisioning of a wide range of multimedia services to end-users. One important ingredient of these services is data or more specifically contextual data accessible or derived from external sources. One of the sources of these contextual data can be WSNs. As of today, WSN provides proprietary interfaces and protocols to access sensor data. Therefore, entities like proxies and gateways are put in place to enable the standard interface for data exchange with other networks (e.g. IMS).

One of the key recommendations made in this chapter is the evaluation of the existing solutions related to the integration of WSN with other networks. This chapter recommends a set of criteria for the integration of WSN with IMS. These criteria were considered for the evaluation of existing solutions. As a result of evaluation it is proffered that 3GPP presence service should be a potential approach for the integration of WSN with IMS. Presence is an important IMS service that enables the development of new communication services (e.g. gaming, Instant Messaging). The main feature of a presence service is to provide user presence and contextual information to applications and other users.

This chapter also recommends the implementation of the integrated WSN/IMS architecture. In order to achieve this, integrated WSN-IMS architecture should be discussed with special emphasis on its implementation. By doing so, such integrated WSN-IMS architecture should provide a generalized communication platform for easy accessibility of sensor data from IMS. It is suggested that the main component of the integrated architecture should be a WSN-IMS gateway that will provide a standard interface (e.g. SIP) for exchanging sensor data. Such a design should also include mapping schemes between WSN and IMS. It is recommended that one of the mappings should include how to map raw sensor data to an abstract IMS format, i.e. PIDF. Another recommendation that should be put into consideration is the mapping of sensors to IMS IDs and the other way around from IMS Ids to sensors. In addition to this, some extensions related to IMS presence service (in Presence Server) for accessibility of WSN data should be implemented. Such extensions should include mechanism to access sensor data i.e. publish upon request (reactive publication) and the presence information modeling i.e. extended PIDF schema for supporting different types of sensor data (spatial, environmental, and physiological).

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