Faculty of Engineering

Ubiquitous Sensor Network in the NGN Environment

Thesis Submitted in Fulfillment of The Requirements for The Degree of
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This work is dedicated to my son David, my lovely wife Miral, my parents, and my brothers Remon & Simon

You gave me love and support

I hope my achievement would draw a smile on your faces

Thanks My Precious Family

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Statement

This thesis is submitted to Ain Shams University for the degree of Doctor of Philosophy in Electrical Engineering (Electronics and Communications Engineering) and is jointly supervised by Pierre and Marie Curie University (UPMC), and Telecom SudParis (France).

The work included in this thesis was carried out by the author at the Electronics and Communications Department (Faculty of Engineering-Ain Shams University) and SAMOVAR laboratory (Telecom SudParis).

No part of this thesis was submitted for a degree or a qualification at any other university or institution.

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Abstract

Ubiquitous Sensor Network (USN) is a conceptual network built over existing physical networks. It makes use of sensed data and provides knowledge services to anyone, anywhere, and at any time, and where the data is generated by using context awareness. USNs and smart wearable devices are emerging rapidly providing many reliable services facilitating people life. Those very useful small end terminals and devices require a global communication substrate to provide a comprehensive global end user service. In 2010, the ITU-T provided the requirements to support USN applications and services in the Next Generation Network (NGN) environment. One of the main promising domains for the USN application and services is the e-Health. It provides continuous patients monitoring and enables a great improvement in medical services. On the other hand, Vehicular Ad-Hoc NETwork (VANET) is an emerging technology, which provides intelligent communication between mobile vehicles. Integrating VANET with USN has a great potential to improve road safety and traffic efficiency.

This thesis proposes the use of the IP Multimedia Subsystem (IMS) as a service controller sub-layer in the USN environment providing a global substrate for a comprehensive end-to-end service. Moreover, the integration of VANETs and USN is proposed for more rich applications and facilities, which will ease the life of humans.

One of the challenges to achieve this goal is the limited capabilities of the sensor network such as bandwidth, low processing power, and memory size. Therefore, there is a need for a protocol that deliver sensors data in an energy-efficient way to the sink. One of those techniques is to gather the sensors data in small size packets suitable for transmission.

First, this thesis proposes a new effective Data Aggregation Protocol (DAP) to reduce the energy consumption in Wireless Sensor Networks (WSNs), which prolongs the network lifetime. This protocol uses in-network aggregation approach to distribute the processing all over the aggregation path to avoid unbalanced power consumption on specific

nodes until they run out. From the simulation results, DAP achieves superior performance and better energy consumption, and consequently extends network lifetime.

Second, a detailed network architecture is proposed for USN based IMS for implementing the proposed e-Health service with emphasizes on middleware layer entities functions. It is simple, flexible, and does not require great changes in the already established communication networks. The thesis provided a detailed network signaling flow for different applicable e-Health scenarios using Session Initiation Protocol (SIP) and proposed a modification in the SIP to match the features provided in the proposed e-Health service. Moreover, emergency cases detection technique is proposed, which is practically vital to save patients life. The evaluation of the proposal proves the ability implement the proposed e-Health scenarios and the reliability of the new signaling model.

Finally, a new end-to-end model for the safety on roads is proposed, that is based on using IMS as a service controller sub-layer to VANETs. Integrating VANET with USN has a great potential to improve road safety and traffic efficiency. Most VANET applications are applied in real time and hence they are sensitive to delay, especially those related to safety and health. Therefore, checking the applicability of any proposed application is very important. One way to achieve this is by calculating the Round Trip Time (RTT), which is the time taken by a VANET application starting from the initiator node (source vehicle) sending a message until receiving a response from the core network. In this thesis, a new complete analytical model is proposed to calculate the RTT of VANET applications. To the best of my knowledge, there is no previous published work that either studied the RTT of VANET applications or developed a complete architecture to implement them by integrating VANETs with USNs and IMS. The RTT is calculated by combining two analytical models. Firstly, an analytical model is developed to calculate the time needed for the communication between two nodes on a road. Secondly, a queuing model using Baskett Chandy Muntz Palacios (BCMP) queuing network is developed for the IMS servers to calculate the proposed application execution time in the core network. These models are general enough to be

applied to any VANET application. Finally, to assess the validity and the accuracy of the proposed architecture and models, three different tools are used: C++, Matlab, and OPNET. The analytical results were compared to the simulation results to evaluate their consistency.

In conclusion, the proposed contributions in this thesis will help to improve the global communication substrate for more applications that are useful for the human life based on the proposed network architecture. In addition, the proposed analytical models will enrich the literature in terms of constructing suitable models to evaluate end-to-end complex networks.

Keywords: Ubiquitous Sensor Network, WSN, Next Generation Network, IP Multimedia Subsystem, Session Initiation Protocol, Vehicular Ad-hoc Network.

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