Ad Hoc Networks 33 (2015) 87–111

Contents lists available at ScienceDirect

Ad Hoc Networks

journal homepage: www.elsevier.com/locate/adhoc

Internet of multimedia things: Vision and challenges

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ARTICLE INFO

Article history:
Received 25 November 2014
Received in revised form 20 April 2015
Accepted 22 April 2015
Available online 7 May 2015

Keywords:
Internet of things
Internet of multimedia things
Wireless communication
Architecture
Multimedia processing

ABSTRACT

Internet of Things (IoT) systems cannot successfully realize the notion of ubiquitous connectivity of everything if they are not capable to truly include 'multimedia things'. However, the current research and development activities in the field do not mandate the features of multimedia objects, thus leaving a gap to benefit from multimedia content based services and applications. In this paper, we analyze this issue by contemplating the concept of IoT and drawing an inspiration towards the perspective vision of 'Internet of Multimedia Things' (IoMT). Therein, we introduce IoMT as a novel paradigm in which smart heterogeneous multimedia things can interact and cooperate with one another and with other things connected to the Internet to facilitate multimedia based services and applications that are globally available to the users. Some applications and use-cases for IoMT are presented to reflect the possibilities enabled by this new paradigm. An IoMT architecture is then presented which is segregated into four distinct stages; (i) multimedia sensing, (ii) reporting and addressability, (iii) multimedia-aware cloud, and (iv) multi-agent systems. Instead of proposing specific technical solutions for each individual stage of the presented architecture, we survey the already existing technologies, providing a synthesis for the realization of the vision of IoMT. Subsequently, various requirements and challenges as well as the feasibility of existing solutions for each stage of proposed IoMT architecture are comprehensively discussed.

1. Introduction

The ever-increasing services and applications offered by the Internet have explosively widen the span of the global inter-network. Currently, over 9 billion network devices are connected to the Internet facilitating more than 2.5 billion people around the globe for communication (emails, social networks, chatrooms, blogs, forums, etc.), Leisure and Entertainment (games, books, music, videos, shopping, etc.), sharing knowledge (education, geographical information, encyclopedias, etc.), among others services. The recent advancements in designing low-cost small scaled devices, enabled by technologies such as Micro Electro Mechanical Systems (MEMS), have harbingered a monumental surge in the number of Internet-enabled devices [1–3]. An explosive growth in the number of devices is forecasted over the next decade. Therefore, in addition to traditional machines, e.g. desktop computers, laptops, mobile phones, etc., the physical objects or things around us will be getting the capability to communicate with each other [4,5].

Smart things equipped with the capability to observe and/or interact with physical environment and the ability to communicate with other things, are extending the Internet towards the so called 'Internet of Things' (IoT) [2,3]. IoT has the potential to significantly influence our lives and the way we interact with the devices such as

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http://dx.doi.org/10.1016/j.adhoc.2015.04.006
1570-8705/

sensors, actuators, mobile phones, home automation devices, and smart grid devices [1]. It has promoted concepts of flexible designs, visions and enormous applications, some of them are depicted in [6–9]. For individual users, IoT brings useful applications in home automation, security, automated devices monitoring and management of daily tasks. For professionals, automated applications provide useful contextual information frequently to help on their works and decision making. For Industrialists, Internet enabled sensors and actuators operations can be rapid, efficient and more economic. Managers who need to keep eye on many things can automate tasks by connecting digital and physical objects together.

Existing surveys on IoT define it in terms of the things' sensing and actuating capabilities, networking, and web technologies, and market potentials; these also, contemplate the hurdles towards standardization and assess its wider implications for society [1–3,5]. However, these research studies do not consider the requirements/challenges posed by multimedia devices or the transportation of multimedia traffic over the network along with other scalar data. Inherent characteristics of multimedia information impose a number of restrictions on the design of IoT, in addition to the challenges imposed by other heterogeneous devices which are part of the IoT. To meet given Quality of Service (QoS) requirements, the network characteristics defined in terms of end-to-end delay, jitter and error rate, among others, are required to be regulated to ensure acceptable delivery of the multimedia content.

There have been enormous growths in multimedia traffic on the global inter-network, due to the huge interest in development and usage of multimedia based applications and services. Real-time multimedia applications, services, and solutions such as video conferencing, remote video-on demand, telepresence, real-time content delivery, and online-gaming, have contributed to the exponential growth of the Internet multimedia traffic. The existing balance between non-multimedia data traffic and multimedia-traffic is now shifting away towards an increase in multimedia content specifically in terms of video content. Recent studies on trends and forecast of global Internet traffic [10] have suggested a definite boost in multimedia traffic flow in next five years. In this regard, Cisco carried out an initiative [11] to forecast the trends of the visual networking applications in the global IP traffic on the Internet. Fig. 1 depicts one of the key findings of this report, in which it is clearly shown that the multimedia (video) traffic will significantly dominate the IP traffic on the Internet. This phenomenon is expected to quickly characterize the word of Internet of Things applications as well.

Multimedia content, e.g. audio, video, etc., acquired from the physical environment possess distinct characteristics as compared to the scalar data acquired by typical IoT devices. On the contrary, the multimedia devices require higher processing and memory resources to process the acquired multimedia information. Moreover, the multimedia transmission is more bandwidth hungry as compared to the conventional scalar data traffic in IoT. Introducing multimedia objects fosters a wide array of applications in both commercial and military domains. Some examples are: real-time multimedia based security/monitory

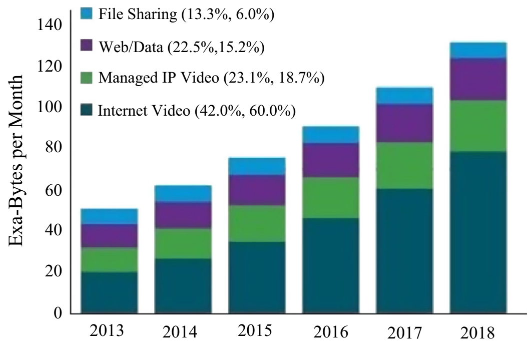

Fig. 1. Global Internet traffic usage and forecast [11].

systems in smart homes, remote patients monitored with multimedia based telemedicine services in smart hospitals, intelligent multimedia surveillance systems deployed in smart cities, transportation management optimized using smart video cameras, remote multimedia based monitoring of an ecological system, etc. However, augmenting IoT systems with multimedia devices and content is not straightforward and requires the introduction of additional functionalities and the revision of existing ones, bringing to a specialized subset of IoT, which we refer to with 'Internet of Multimedia Things' (IoMT).

The physical environment information acquired by the traditional wireless sensor devices in IoT may include statistics about light, temperature, pressure, etc., and the things reporting their conditions/states such as the water level in a water-dispenser, battery status or fault reporting for predictive maintenance. The nature of this sensed data is periodic and requires less memory and computational resources. Thus, these applications demand simple processing capability and lower data rates at the sensing device. On the contrary, the multimedia data in IoMT is bulky in nature and specifically for real-time communication higher processing and memory resources are required. Therefore, the multimedia acquisition and communication by current IoT devices is not realizable.

In IoMT, the delivery of multimedia data should be within the bound of QoS constraints (i.e. delay, jitter) which obligate higher bandwidth and efficient communication mechanisms. The routing protocol RPL in current IoT communication stack is flexible and adaptive to operate in energy efficient way as per the application requirements. Yet the current MAC and PHY layer (e.g. ZigBee) proposed for IoT only supports a theoretical data rate of 250 kbps, which is far less than a typical multimedia based application's requirement. These protocols are adopted for IoT communication stack due to their energy efficient operation. Recently, low-power IEEE 802.11 devices supporting much higher data rates are being designed, for example Qualcomm's QCA-4002 and QCA-4004-Qualcomm [12], MICROCHIP's RN171 [13].

In an IoT based system intelligence and action triggering capability is embedded in the devices with the help of sensors and actuators, respectively. Similarly, a cloud enables the capability to develop, maintain, and run, different services by providing scalable computing and storage