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Energy-efficient device-differentiated cooperative adaptive multimedia delivery solution in wireless networks

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ABSTRACT

There is very much interest in balancing remote delivered multimedia quality and energy consumption in a heterogeneous wireless network environment. This paper proposes a solution for Energy-efficient Device-differentiated Cooperative Adaptive Multimedia Delivery over wireless networks (EDCAM), a hybrid innovative approach which combines multimedia quality adaptation and content sharing mechanisms to save energy at client devices according to their different characteristics. EDCAM relies on an automatic application-aware device profiling, which is proposed to assess individual *device energy constraints*. These constraints along with QoS delivery scores are used as metrics for the multimedia delivery quality adaptation. Devices make use of content sharing partners with which retrieve the content cooperatively, reducing the usage of high energy consuming networks and therefore increase the delivery energy efficiency.

Simulation tests in a WiFi and LTE-based heterogeneous wireless network environment with increasing number of video flows and users show how the proposed EDCAM solution results in significant improvements of up to 40% in terms of energy efficiency in comparison with three other state-of-the-art solutions, while maintaining the performance of multimedia content delivery and estimated user perceived quality at the highest levels.

1. Introduction

The latest developments of wireless communication technologies in terms of mobility and scalability enable mobile devices to inter-connect people and devices anywhere and at anytime. The global smart device market grew 25.3% year over year in the second quarter of 2014 alone and the number of mobile network-connected devices shipped in a quarter has exceeded the 300 million unit mark, representing an outstanding record for this industry to date (Llamas et al., 2014). It is expected that over 1.25 billion smartphones will be shipped worldwide in 2014, representing a 23.8% increase in comparison with the similar number in 2013 and more than 1.8 billion units in 2018, resulting in a 12.7% compound annual growth rate between 2013 and 2018 (Llamas et al., 2014). Cisco estimates handsets will generate in excess of 50 percent of mobile data traffic in 2014, and the video content will account for more than two thirds of the globe networking traffic by 2016 (Cisco visual networking index, 2012). This trend is made possible by the multimedia capability support and ubiquitous network connectivity provided by the latest smart mobile devices.

As the number of increasingly powerful mobile devices such as smart phones and tablet PCs grows, and they run many and more diverse communication and rich media-based applications, they play increasing important roles in people's life. Mobile devices are used everywhere for example in airports, on the street, in coffee shops and conference centres, for work and entertainment, for communications, computations or presentations. Notably, recently more than half of the Internet searches were performed from mobile devices (Richmond, 2011); multimedia-based traffic accounts for 49 percent and 53 percent of the total data consumption over smartphones and tablets, respectively (Cisco visual networking index, 2012).

The latest mobile devices are designed to be complex, but compact, and therefore it is a requirement to be powered by slim and light batteries. These batteries have limited lifetime and consequently energy-efficiency is a key issue. Many energy saving solutions have been proposed, including communication-oriented mechanisms (Chen et al., 2011; Yan et al., 2006; Saha et al., 2011; Ding and Muntean, 2012a,b). In the context of multimedia content delivery, adaptive solutions have been proposed to improve the energy efficiency of multimedia transmissions and remote playout,

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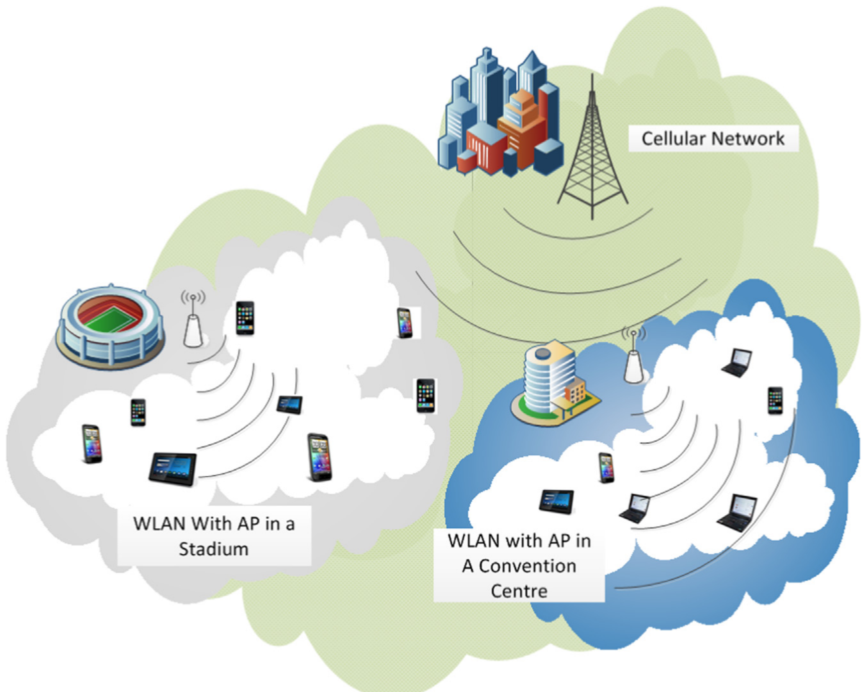

Fig. 1. An illustration of a heterogeneous wireless network environment.

while also maintaining high levels of quality of service (QoS) (Shmueli et al., 2008; Yu et al., 2011; Alt and Simon, 2010; Li et al., 2006; Kim et al., 2009). Some of these adaptive solutions are specific to wireless deliveries to mobile devices (Park et al., 2005; Park and Ogunfunmi, 2011; Adams and Muntean, 2007; Ding and Muntean, 2013; Kennedy et al., 2010; Trestian et al., 2009; Kaddar and Mehaoua, 2007; Kaddar et al., 2011).

There are various technologies (e.g. WiFi, WiMax, and LTE) to support wireless networking in hot spots, at home or within company premises which establish a heterogeneous wireless network environment providing ubiquitous connectivity to smart devices, as illustrated in Fig. 1. Different network interfaces are associated with these technologies and consequently they have different characteristics in terms of transmission bandwidth and energy efficiency. Therefore exchanging content between devices by utilising diverse network interfaces gives opportunity to improve the performance of wireless content delivery and multimedia content in particular. This is especially useful when multimedia is delivered to mobile devices in places with many people, where many individuals may require access to the same content.

In such scenarios, there are major challenges. Some networks are often congested when people density is high; others have lower bandwidth. Some solutions (Liu et al., 2009; Saha et al., 2011; Hsieh and Sivakumar, 2004; Liu et al., 2011; Stiemerling and Kiesel, 2010; Luo et al., 2007) propose using mobile ad hoc networks (MANET) to form sharing groups to help overcome congestion or save energy. However very much effort is put into group management, which offsets the energy saving benefit on the client side. Additionally, multi-hop transmissions affect seriously the throughput (Hsieh and Sivakumar, 2004) and solutions extend also in the wireless ad hoc (Diaz et al., 2014a,b) and wireless sensor networks (Rosário et al., 2012; Atto and Guy, 2014) space.

Other solutions save energy by performing quality adaptation based on device battery energy level and network conditions only (Moldovan et al., 2011, 2013). Park et al. (2005) change the quantisation parameter for blocks in the video decoder for energy saving. They develop a dedicated chip for scalable video coding content delivery (Park and Ogunfunmi, 2011). ESTREL (Kaddar and Mehaoua, 2007) and EVAN (Kaddar et al., 2011) adapt video quality to the remaining battery level of mobile devices. Adams and Muntean (2007) reduce the frequency of client wake ups by buffering traffic at access point and changing the timing for sending data traffic. Trestian et al. (2009) adjust video quality to remaining energy level and signal strength. Similarly Kennedy et al. (2010) adapt video quality to the remaining energy level and video duration. The above solutions consider devices in the same context. Along with the video delivery application, devices may simultaneous run multiple applications with different power demands that propose different energy constraints on the devices. Hence a comprehensive application-aware energy modelling is needed. The modelling will assist the implementation of device differentiated multimedia content adaptation.

Devices with different energy constraints require content of different quality to prolong battery life. Even energy-oriented content sharing schemes (Chen et al., 2011; Sharma et al., 2009; Liu et al., 2009) fail to address such issues. This is because they assume the available content is of the same quality, and allow a group of devices to share the content of the same quality among them. This assumption obviously does not perfectly suit current trends of offering content of multiple quality to suit various user preferences. Quality adaptation and device differentiation are not considered either.

Going beyond the existing state-of-the-art, this paper introduces a novel *Energy-efficient Device-differentiated Cooperative Adaptive Multimedia Delivery Solution* (*EDCAM*) for heterogeneous wireless networks such as the one illustrated in Fig. 1. The proposed *device differentiated* solution includes application-aware device profiling and energy efficient quality adaptation to suit individual device characteristics. EDCAM considers both *interest in content* and *device required quality level* in its *adaptive cooperative delivery* process.

EDCAM's multimedia delivery process employs a cooperative behaviour and uses one neighbouring device with the same interest in the content as partner for multimedia content sharing. The partner selection is based on energy-oriented device characteristics. EDCAM also uses a quality-based adaptation algorithm