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CONTENTS

Message from MMTC Chair

Dear MMTC colleagues:

How time flies by! It has been almost a year since the new leadership team was confirmed at ICC 2014 in Sydney. Over this past year, the team has worked together to move forward all the existing programs and start a couple of well-accepted new initiatives. In this letter, it is with my greatest pleasure to report some of our new initiatives.

First, we have reorganized our signature Special Interest Groups. This initiative was inspired by a message from IEEE ComSoc Technical Activity Committee to revisit all the technical committees. We have decided to move first to realign our IG program to ride on the emerging trends of new technologies and attract more volunteers. Using this principle, we have merged four existing Interest Groups into two Interest Groups and introduced three new Interest Groups, covering the emerging topics of cloud computing, big data and systems. Up to now MMTC has 14 Interest Groups, each of which is run by a Chair, supported by two co-chairs and at least one technical advisor. With the newly formed structure, we have seen that all the IGs are operated well so far. Thanks a lot for all the volunteers.

Second, we have streamlining the process for new members to join MMTC. It has been brought to our attention that the process of join MMTC was too complicated. The membership team, led by Dr. Shiwen Mao, has been working to streamline this process. The team has designed and are implementing a new page on MMTC website to make the membership enrolment effortless for new members. I would like to seek your support to forward the message to your friends and colleagues who are interested in joining MMTC upon receiving our announcement.

Third, we have introduced a (weekly) newsletter for membership communications. This newsletter covers a few items including: i) messages from our members, ii) table of contents for related transactions and magazines, iii) call for papers and iv) other relevant messages. The objective is to reduce the traffic broadcast to the MMTC mailing list. Currently Dr. Fen Hou is handling the editing of this newsletter. In next few weeks, we are recruiting a dedicate editor to manage the newsletter. If you are interested in contributing, please contact me (ygwen@ntu.edu.sg) and Dr. Fen Hou (fenhou@umac.edu).

Four, we have been strengthening our collaboration with relevant journals and conferences. MMTC is formally involved two journals (i.e., IEEE T-MM and IEEE Multimedia Magazine). Over last year, we have been working closely with the editors in chief of both journals to recommend special issues and promote our visibility. We are also involved with three conferences including ICC, Globecom and ICME. Our main thrust has been to increase our submissions to these conferences. Therefore, I would like to extend an invitation to all our MMTC members to submit your papers to CSSMA symposium at ICC/Globecom and ICME in future.

Finally, I would like to thank all the existing IG chairs and other volunteers for the work they have already done and will be doing for the success of MMTC and hope that any of you will find the proper IG of interest to get involved in our community!

Yonggang Wen
Chair, Multimedia Communications Technical Committee, IEEE ComSoc

EMERGING TOPICS: SPECIAL ISSUE ON QOE MANAGEMENT FOR NEXT GENERATION MULTIMEDIA SERVICES

Guest editors: Lea Skorin-Kapov[1], Hantao Liu[2], and Martín Varela[3]

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Recent years have seen very significant advances in QoE modeling and understanding. Most of these works have focused on identifying the system-, context-, and user-related factors impacting QoE. However, a still outstanding key issue to address is the exploitation of this knowledge for the purpose of controlling and optimizing QoE. This Special Issue of the MMTC E-Letter focuses on different aspects of QoE management for next generation multimedia services as considered from multiple stakeholder perspectives, ranging from technical to economic considerations and challenges.

The first paper "Quality of Experience of Adaptive HTTP Streaming in Real-World Environments" by *Christian Timmerer*, *Matteo Maiero*, *Benjamin Rainer*, and *Stefan Petscharnig* focuses on QoE for media services based on MPEG-DASH. The paper summarizes the results of a crowdsourced QoE study conducted in real-world environments comparing different state-of-the-art adaptation logics presented in literature and one commercial implementation from Bitmovin. Implementations are compared with respect to average media throughput, number of stalls, and MOS. In their conclusions, the authors stress the need to combine knowledge regarding average media throughput at the client with other metrics, such as the number of stalls and quality switches, when assessing the performance of MPEG-DASH clients.

The second paper, entitled "Towards QoE Provisioning in Next Generation Cellular Networks", authored by *Eirini Liotou*, *Nikos Passas*, and *Lazaros Merakos* addresses QoE from an mobile operator's perspective. The authors present the basic elements of a QoE provisioning framework and focus specifically on the principals of implementing them in mobile cellular networks. They further discuss the concept of service delivery based on *experience packages*, derived by matching user profiles, service/application requirements, context information, and network capabilities. The potential impacts of context-based provisioning are highlighted with examples.

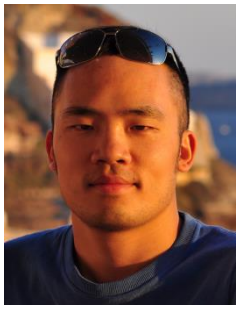
Further addressing mobile networks, the third paper "QoE-driven Management Schemes for Multimedia Services" by *Lingfen Sun* and *Ali Alfayly*, presents an approach to applying a general QoE model in QoE management schemes for multimedia services. The paper discusses QoE model application in an LTE downlink scheduling scheme and demonstrates how the proposed QoE-driven approach can increase the number of users a mobile node can support while maintaining acceptable QoE for mobile users. Such an approach is of particular interest in emergency mobile communications or at major events/gatherings involving many users.

The fourth paper "QoE-Aware Routing for Video Streams", authored by *Doreid Ammar*, proposes a novel mechanism for deciding whether video traffic should be routed on a given route path by estimating the perceived quality it would have, based on the current load on said path. Network conditions are monitored in real-time and used to make adaptive traffic- and QoE-aware routing decisions. The proposed mechanism allows achieving a near-optimal trade-off between link utilization and QoE.

Finally, the fifth paper "The Economics of Quality of Experience: Recent Advances and Next Steps", authored by *Peter Reichl* and *Patrick Zwickl*, links QoE to the business aspects of providing a service, from pricing - using fixed-point models - to customer experience management and other business aspects such as SLAs. The authors also provide a list of key challenges that need to be addressed in making the shift from QoS to QoE on the business side of services and drawing a closer link between quality differentiation and pricing.

The papers included in this Special Issue cover different aspects of QoE management, going from QoE modeling considerations to actual exploitation of such models in the network from a technical and business point of view. We would like to thank all the authors for their contributions and hope that the papers will provide valuable insight to the E-Letter readership.

Lea Skorin-Kapov is an Assistant Professor at the University of Zagreb, Croatia where she received her MSc and PhD degrees in 2004 and 2007, respectively. She has over 8 years of previous experience in industrial research as a senior researcher and project manager in the R&D Center of Ericsson Nikola Tesla, Zagreb, Croatia, working in the areas of QoS signaling and negotiation for multimedia services. Her main research interests are related to QoE modeling of interactive multimedia and Web-based applications, and management/optimization of QoS/QoE. She has participated in a number of industry and research projects focusing on QoS/QoE, and has been the Croatian MC member in COST Actions IC1003 Qualinet and IC1304 ACROSS. She is currently serving as Chapter vice-chair of the IEEE ComSoc Croatia Chapter, and is co-chair for the MMTC QoE Interest Group.



Hantao Liu received the MSc degree from the University of Edinburgh (United Kingdom) and the PhD degree from the Delft University of Technology (The Netherlands) in 2005 and 2011, respectively. His PhD thesis focused on Modeling Perceived Quality for Imaging Applications. In 2012, he joined the University of Hull (United Kingdom) as an Assistant Professor in Computer Science, leading research Computational Perception and Image Computing. He served as a Management Committee member (UK representative) for the COST Action IC1003 Qualinet: European Network on Quality of Experience in Multimedia Systems and Services. He is now serving for IEEE MMTC as Chair of the Interest Group on Quality of Experience for Multimedia Communications. His research interests include visual media quality assessment, visual attention modeling and applications, visual scene understanding, medical image perception, and user experience in healthcare.

Martín Varela received his PhD and MSc from the University of Rennes (Rennes, France), in 2005 and 2002 respectively. He has been an ERCIM fellow, and spent time at SICS and VTT, where he is currently a Principal Scientist. His research interests lie in the QoE domain, with a particular focus on real-time QoE estimates for media and cloud services and applications thereof. He is currently leading VTT's work on QoE, and has served as Finnish management committee member for COST Actions IC1003 Qualinet and IC1304 ACROSS. He has also served as Scientific Coordinator for the Celtic Plus QuEEN project. He is currently co-chair for the IEEE MMTC QoE Interest Group.

Quality of Experience of Adaptive HTTP Streaming in Real-World Environments

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1. Introduction

Real-time entertainment services such as streaming video and audio are currently accounting for more than 60% of the Internet traffic, e.g., in North America's fixed access networks during peak periods [1]. Interestingly, these services are all delivery over-the-top (OTT) of the existing networking infrastructure using the Hypertext Transfer Protocol (HTTP) which resulted in the standardization of MPEG Dynamic Adaptive Streaming over HTTP (DASH) [2]. The MPEG-DASH standard enables smooth multimedia streaming towards heterogeneous devices and commonly assumes the usage of HTTP-URLs to identify the segments available for the clients [3].

In this paper we focus on the Quality of Experience (QoE) of DASH-based services. We provide a general definition of QoE and which parameters are important for media services based on MPEG-DASH. The core of the paper comprises results of a QoE evaluation of different adaptation logics proposed in the research literature and also one commercially available implementation from bitmovin within real-world environments.

2. Quality of Experience for Dynamic Adaptive Streaming over HTTP

Quality of Experience

The term Quality of Experience (QoE) can be seen as an evolution from the term Quality of Service (QoS), both defined by the ITU-T in P.10/G.100. QoS is defined as the "totality of characteristics of a telecommunications service that bear on its ability to satisfy stated and implied needs of the user of the service" whereas QoE is defined as "the overall acceptability of an application or service, as perceived subjectively by the end-user". Although this definition was largely used (but not necessarily agreed), one could easily understand that acceptability is only one aspect of quality, as one may accept a service – depending on the context – but not necessarily be happy or satisfied. Therefore, the COST Action IC1003 – QUALINET goes a step beyond and defines QoE as "*the degree of delight or annoyance of the user of an application or service. It results from the fulfillment of his or her expectations with respect to the utility and/or enjoyment of the application or service in the light of the user's personality and current state*" [4].

The QUALINET white paper even goes further and defines influence factors as "any characteristic of a user, system, service, application, or context whose actual state or setting may have influence on the Quality of Experience for the user" which are grouped into human, system, and context influence factors. Additionally, features of QoE are provided depending on the level of direct perception, interaction, the usage situation, and service. A QoE feature is thus defined as "a perceivable, recognized and namable characteristic of the individual's experience of a service which contributes to its quality".

As the definitions above are very generic we will next describe what it means for DASH-based services.

QoE factors impacting DASH

Different application domains may have different requirements in terms of QoE. Thus, there is a need to provide specializations of a generally agreed definition of QoE (see above) pertaining to the respective application domain taking into account its requirements formulated by means of influence factors and features of QoE. Consequently, an application-specific QoE definition can be provided by selecting the influence factors and features of QoE reflecting the requirements of the application domain and incorporating them into the generally agreed definition of QoE.

For DASH-based services the main QoE influence factors can be described as *initial/start-up delay*, *buffer underruns* also known as *stalls*, *quality switches*, and *media throughput*.

The initial or start-up delay comprises the time between service/content request and start of the actual playout which typically involves processing time both at the server and client, network time for sending the MPD request and receiving first segments, and initial buffer time before the playout starts. In general, the start-up delay shall be low but it also depends on the use case. For example, the QoE of live streams or short movie clips is more sensitive to start-up delay than full-length video on demand content.

A stall occurs when the video/picture freezes that is typically caused due to buffer underuns and playback is

resumed if enough segments have been re-buffered. In practice, users experiencing stalls usually report a very low QoE and, thus, stalls shall be avoided at all, even if it means increasing the start-up delay.

In changing network conditions quality switches occur to avoid buffer underruns (and stalls) in order to guarantee a smooth video playback. However, if it happens too often (e.g., every second) or with a high amplitude (e.g., switching from a very high quality to a very low quality representation) it may negatively impact the QoE.

Finally, the overall media throughput at the client measured in media bits per second and a higher media throughput usually means higher QoE but it should be never used alone and always in conjunction with the above metrics as we will see in the experimental results.

The above-mentioned parameters focus on the context, specifically on delivery and device characteristics but QoE is about the users consuming content and services. Thus, it is important to understand the way how the content is provided for DASH-based services as this directly influences the QoE. In particular, this means how many different representations are available and in which qualities (incl. bitrate, resolution, etc.) and the actual segment length (e.g., 2s vs. 10s). Additional parameters are the available languages, existence of subtitles, closed caption, or any other means that help impaired users to consume the content more conveniently. In this paper we focus on the context parameters, different segment lengths, and assume a broad range of different representations available from which the client can select.

3. QoE Evaluation of DASH-based Services

Methodology

The *test sequence* is based on the DASH dataset [5] where we adopt the Big Buck Bunny sequence that we encoded with bitcodin – a cloud-based transcoding as-a-service, http://www.bitcodin.com/ – in order to get the representations with a bitrate of 100, 150, 200, 350, 500, 700, 900, 1100, 1300, 1600, 1900, 2300, 2800, 3400, 4500 kbps and resolutions ranging from 192×108 to 1920×1080. The configuration provides a good mix of resolutions and bitrates for both fixed and mobile network environments. In fact, we provide two versions, one with a segment length of 2s and the other with 10s that are the most common segment sizes currently adopted by actual deployments (i.e., Apple HLS uses 10s whereas others like Microsoft and Adobe use 2s).

For the actual *MPEG-DASH client* we adopt our bitdash streaming framework – http://www.dash-player.com/ – and compare it with ten different adaptation algorithms reported in the research literature.

For the *objective evaluation* we adopt the setup according to [6] where the bandwidth and delay between a server and client are shaped using a shell script, that invokes the Unix program TC with netEM and a token bucket filter. In particular, the delay was set to 80ms and the bandwidth follows a predefined trajectory (alternatively, real-world bandwidth traces could be used [6]). The delay corresponds to what can be observed within long-distance fixed line connections or reasonable mobile networks and, thus, is representative for a broad range of application scenarios. The bandwidth trajectory contains both abrupt and step-wise changes in the available bandwidth to properly test all the adaptation logics under different conditions.

For the *subjective evaluation* we adopt a crowdsourcing approach that uses the Microworker platform – https://microworkers.com/ – to run such campaigns and to recruit participants, which are actually referred to as microworkers. The content server is located in Europe and, thus, we limit participants to Europe in order to reduce network effects due to proxies, caches, or content distribution networks (CDNs) that we cannot control.

At the end of the subjective evaluation, each microworker needs to hand in a proof that she/he has successfully participated which is implemented using a unique identification number. We set the compensation to US$ 0.4, which is the minimum compensation for this type of campaign at the time of writing this paper.

The stimulus is the same as for the objective evaluation but we added another sequence – an excerpt from Tears of Steel, also available at [5] in order to mitigate any bias that may be introduced when using only one type of content. The content configuration is the same as for Big Buck Bunny but we used only one segment size of 2s.

The goal of this evaluation setup is to provide objective metrics which are collected at the client to be analyzed during the evaluation. These metrics include the observed bitrate, selected quality representation, buffer level, start-up delay, and stalls (re-buffering due to underruns).

The subjective evaluation methodology comprises an introduction, a pre-questionnaire, the main evaluation, and a post-questionnaire. The introduction explains the structure of the task and how to assess the actual QoE asking the microworker to provide an honest response. The pre-questionnaire collects demographic data like country of residence that we use later to filter participants. The main evaluation comprises a Web site presenting the stimulus (both sequences) with a gray background as recommended in Rec. ITU-R BT.500-11. The content is actually streamed over the open

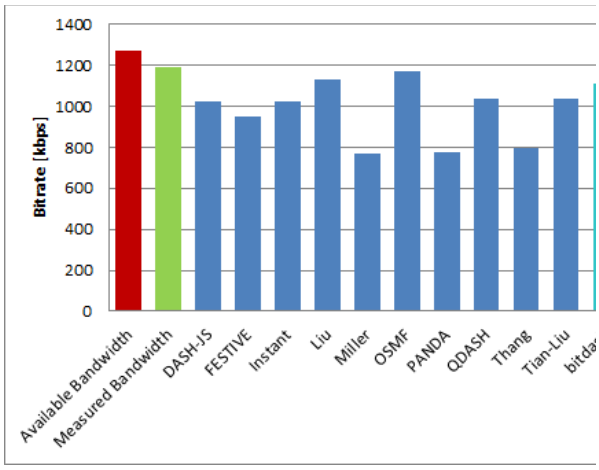

Figure 1: Average Media Throughput/Bitrate of all Adaptation Logics (higher is better).

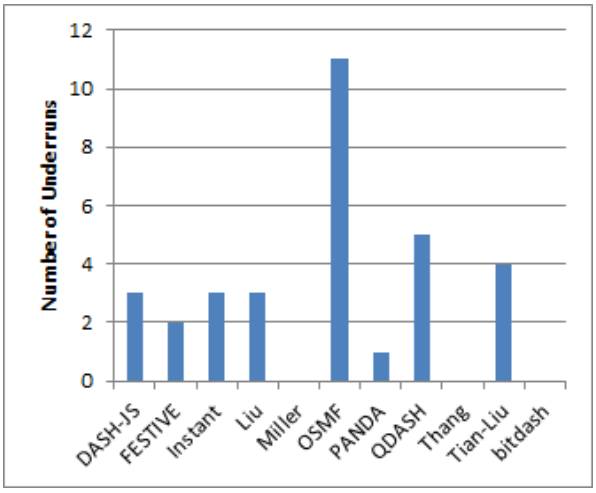

Figure 2: Number of Buffer Underruns/Stalls (lower is better).

Internet to which the microworker is connected using a JavaScript-based DASH client with one of the available adaptation logics. The selection of the adaptation logic is uniformly distributed (p=1/10) among the participants and the size of DASH client is fixed to a resolution of 1280×720 pixels. After the stimulus presentation, participants rate the QoE using a slider with a continuous scale from 0 to 100. The slider is initially set to 50 (middle position) and the time for rating the QoE is limited to eight seconds. The stimulus – both sequences – is presented in random order to the participants. Finally, the post-questionnaire gathers any feedback from the participants using a free text field.

In addition to the QoE rating we gather various objective metrics such as number of stalls (i.e., buffer underruns), and the average media throughput of the client.

This methodology enables a subjective evaluation of different DASH adaptation logics within real-world environments as opposed to controlled environments and, thus, provides a more realistic evaluation of adaptive HTTP streaming systems. However, using crowdsourcing requires a more careful evaluation of the participant's feedback. Therefore, we filtered participants using browser fingerprinting, stimulus presentation time, actual QoE rating, and feedback from the pre-questionnaire.

In the following sections we provide the results of the objective and subjective evaluations.

Results

The average media throughput in terms of bitrate [kbps] is shown in Figure 1. The "Available Bandwidth" on the left side of the figure shows the average bandwidth according to the predefined bandwidth trajectory used in the evaluation. The "Measured Bandwidth" by the clients is shown next to it, which is typically a bit

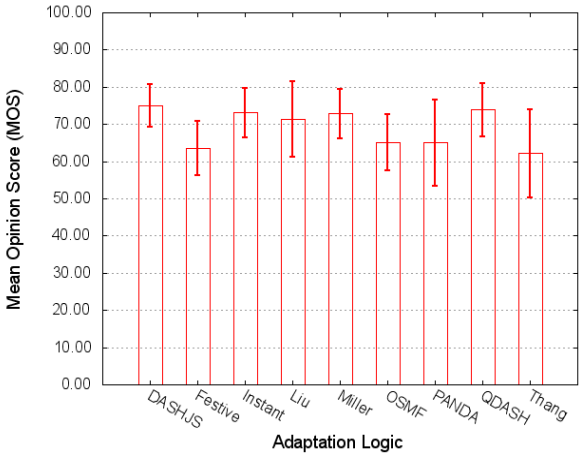

Figure 3: Mean Opinion Score (MOS) per Adaptation Logic with a 95% Confidence Interval.

lower than the available bandwidth due to the network overhead. The results of the different adaptation logics is shown subsequently and bitdash – on the very right side of the figure – is among the top three implementations, namely 1. OSMF (1170.65 kbps), 2. Liu (1129.69 kbps), and 3. bitdash (1109.43 kbps). However, taking into account the average media throughput only is a fallacy when investigating the number of stalls as depicted in Figure 2. Interestingly, among the top three, only bitdash does not produce any stall whereas the client with the best average media throughput produces the highest number of stalls, obviously not good for high QoE.

For the subjective evaluation, in total 220 microworkers participated in the subjective quality assessment from which 19 participants were excluded from the evaluation (due to issues during the crowdsourcing test as outlined in Section 3.3). From the remaining 201 participants were 143 male and 58

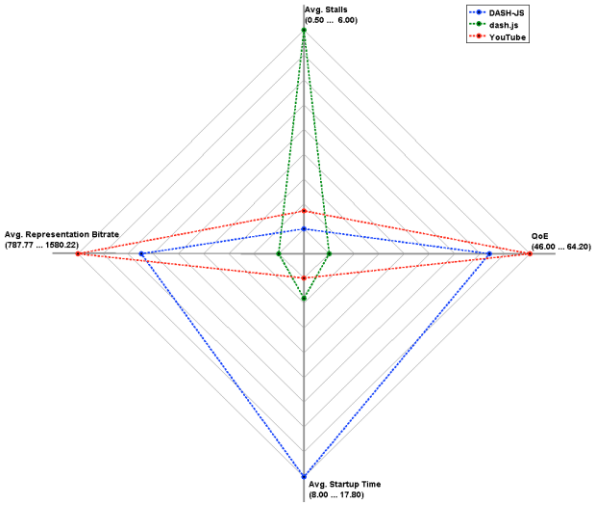

Figure 4: Overview of the Results for the Evaluated DASH-enabled Web Clients [7].

female with an average age of 28. The results presented in this section reflect the behavior of the adaptation logics in a real-world environment with subjects spread across Europe accessing the test sequences over the open Internet.

Figure 3 depicts the QoE in terms Mean Opinion Score (MOS) per adaptation logic (95% confidence interval). Interestingly, DASH-JS (and also Instant) provides the highest MOS value but due to overlapping confidence intervals relatively little can be stated whether it performs significantly better than the other algorithms. However, it provides a good indication about its effectiveness in a real-world environment. OSMF does not have the lowest MOS value despite its worse performance during the objective evaluation. In particular, Thang has the lowest MOS value – during the objective evaluation – although it does not cause any stalls but comes with a relatively low media throughput for both segment sizes.

Finally, we would like to share insights from a different study comparing DASH-JS, dash.js (DASH-IF reference player available at http://dashif.org/), and YouTube [7].

Figure 4 shows an overview of the results along four dimensions: average representation bitrate (i.e., media throughput at the client), average startup time (or startup delay), average number of stalls, and the QoE in terms of Mean Opinion Score (MOS). DASH-JS maintains the lowest number of stalls (0.5 stalls on average) and the average representation bitrate is about 1,330 kbit/s. However, DASH-JS has the highest average startup time. The reason for this high startup time is that DASH-JS estimates the initial bandwidth when downloading the MPD and, thus, may select a higher bitrate in the beginning than the other clients. dash.js is outperformed by the other two DASH-enabled Web clients in three of the four dimensions. In particular, dash.js provides the lowest average representation bitrate, the highest number of stalls, and the lowest QoE. YouTube outperforms all other clients in three cases, specifically in the representation bitrate, startup time, and QoE. Furthermore, **Figure 4** indicates a correlation between the number of stalls and the QoE and that the representation bitrate impacts the also QoE but is not solely responsible for the QoE.

4. Conclusions

In this paper we have presented means for the Quality of Experience (QoE) evaluation of MPEG-DASH clients using objective/subjective measures and in controlled/real-world environments. An important finding is that the average media throughput/bitrate at the client cannot be used alone to describe the performance of MPEG-DASH clients and needs to be combined with other metrics such as the number of stalls. Interestingly, the start-up delay does not necessarily influence the QoE but buffer underruns or stalls will definitely and also significantly impact the media experience and, thus, shall be avoided at all.

The findings presented in this paper provide useful insights for current and future deployments of adaptive media streaming services based on the MPEG-DASH.

Acknowledgment: FFG project AdvUHD-DASH.

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Towards QoE Provisioning in Next Generation Cellular Networks

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1. Introduction

Quality of Experience (QoE) is defined as "the degree of delight or annoyance of the user of an application or service" [1]. The inherent subjectivity in this definition explains the fact that QoE research has attracted interest from multiple disciplines and has been studied from various angles. In this work, we address QoE from a telecom operator's perspective, providing insights towards enabling QoE provisioning in the next generations of cellular networks.

In cellular networks, despite the catholic presence of inherently deployed Quality of Service (QoS) mechanisms, QoE has been more of an "afterthought". This means that previous and existing network generations have not been inherently designed with QoE principles in mind. It is envisioned, however, that the next, i.e. 5th, generation of communication networks will be more user-centric, designed to deliver consistent experience to the users and to give them the perception of "infinite capacity" [2].

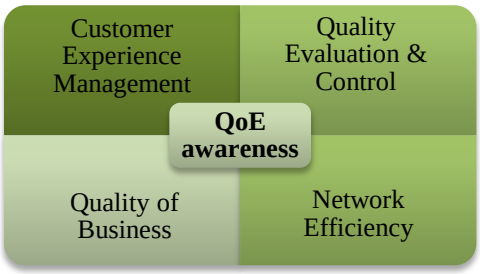

Figure 1 – The importance of QoE awareness.

Towards that direction, the acquisition of QoE awareness and the management of a network in a QoE-centric way become essential. QoE intelligence can be valuable to telecom operators, Over-The-Top (OTT) service providers, and any other stakeholders involved in the service delivery chain. Focusing on the telecom operators' perspective, we may identify four potential opportunities (and incentives, thereof) that derive from acquiring QoE knowledge and controlling a network in a QoE-centric way. As also illustrated in Figure 1, the main motives are the following: a) To enable customer experience management and enhancement solutions by performing QoE-oriented data analytics (e.g. automate service configuration, facilitate self-care and self-diagnosis, etc.); b) To drive business operations, facilitate strategic decisions and build more meaningful Service/Experience Level Agreements (SLAs/ELAs); c) To decrease churn, first by comprehending the end-users' and applications' QoE requirements and then by controlling the network accordingly (namely, avoid under-engineering); and finally, d) To increase the network efficiency through identifying and exploiting the non-linear relationships between technical QoS parameters and the finally perceived QoE (namely, avoid over-engineering in spectrum, energy, etc.).

2. QoE provisioning

QoE provisioning or QoE management refers to the exploitation of QoE intelligence towards a more effective and efficient network control, both to the end-users' and the network operator's advantage. A high-level QoE provisioning architecture is presented in Figure 2. In this design, an intelligent QoE entity is implemented at a central, administrative location inside the operator's network, on top of the network infrastructure, depicted in Figure 2 as a cloud (its exact location is currently out of focus). This central entity is able to obtain QoE-related input from appropriate network elements and to apply QoE-driven network management decisions. It consists of three main building blocks, namely the QoE-Controller, QoE-Monitor and QoE-Manager [3].

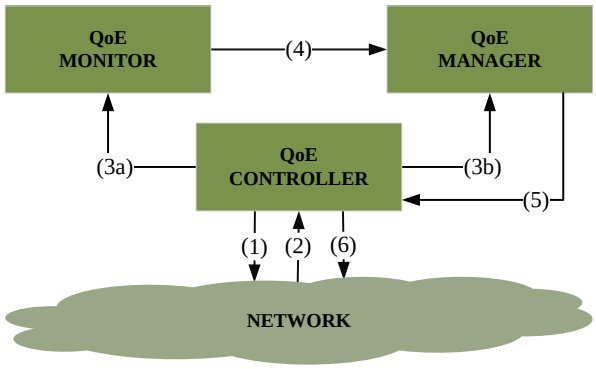

Figure 2 – High-level QoE provisioning framework [3].

The QoE-Controller plays the role of an interface between the central QoE entity and the network infrastructure, and it is in charge of a) synchronizing the QoE-related data acquisition process (requests (1) and replies (2) in Figure 2), and b) imposing any QoE-related management decisions back to the network (6). The QoE-Monitor implements the QoE estimation functions (a.k.a. objective QoE models), namely it is running the appropriate QoE function per traffic flow. To operate, it uses input provided by the QoE-Controller (3a), namely, $QoE = f(input1, input2, \ldots)$.

This QoE prediction/estimation is then provided as input to the QoE-Manager (4). The latter, combines the received QoE estimation with awareness about the current network topology and state (3b), in order to trigger any QoE-centric network management decisions (5) through the QoE-Controller (6).

Focusing on each one of these building blocks, we have to investigate the fundamentals and basic principles of implementing them in mobile cellular networks. Concentrating more on the QoE-Manager component, we may as well propose novel QoE-driven mechanisms to control and improve the QoE offered to the end-users. For instance, in [4], a network management framework is presented that exploits QoE awareness for controlling the operational mode of mobile users in Long Term Evolution-Advanced (LTE-A) networks that support Device-to-Device (D2D) communications. Specifically, a method for controlling the transition of cellular links to D2D links or vice-versa is described, driven by the end-user's benefit, as this is quantified using the ITU-T G.107 model (VoIP services). Simulations in [4] demonstrate the expected gains of this method, both for the end-users (increase in Mean Opinion Scores (MOS)) and the network operators (increase in offered throughput).

Furthermore, in [3], it is described how the aforementioned QoE management framework may be customized and applied for the purposes of implementing a real-time QoE-aware Admission Controller (AC) in a heterogeneous cellular environment (Figure 3a). A scenario is studied, where the user density in an outdoors small-cell is gradually increasing, and the end-users are admitted on the basis of preserving an acceptable QoE threshold inside the small-cell. In contrast with conventional admission control mechanisms with position- or received signal strength-admission criteria (Figure 3b), proposed in [3] are QoE-admission criteria, which manage to keep the average quality of the users in both the macro- and the small-cell at satisfactory levels (Figure 3c).

Moving one step further, QoE awareness can also be exploited in order to save redundant resources from the network, by identifying and avoiding "over-engineering" cases. For instance, described in [5] is the introduction of QoE intelligence to the estimation of the required transmission power of base stations in a femto-overlaid cellular network. Specifically, a method is described to decrease the transmission power of all involved base stations (evolved-NodeBs (eNBs) and Home-eNBs) in order to cause the minimum, but still sufficient Signal-to-Interference-plus-Noise Ratio (SINR) at the target devices (macro-users and femto-users, respectively), without any negative impact on their perceived quality. The proposed QoE-aware scheme can be applied as an additional rule on top of existing power control schemes, allowing for energy

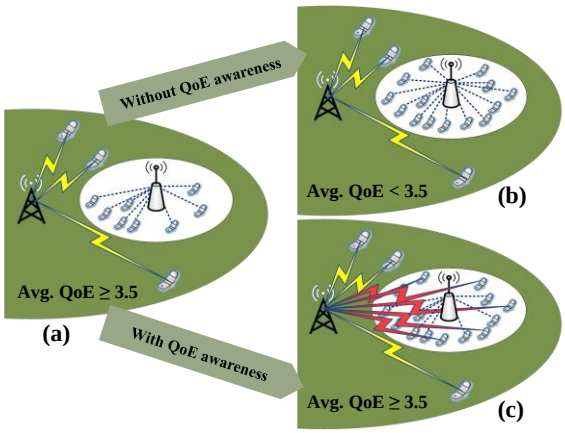

Figure 3 – a) Low-loaded small-cell, b) High loaded small-cell, conventional AC scheme, c) Load distributed among macro- and small-cell, QoE-aware AC scheme.

savings, without sacrificing the quality of the offered service. This is made possible by exploiting the "constant optimal" region described in the IQX hypothesis [6].

3. The concept of "experience packages"

Assuming the existence of a high-level QoE provisioning framework, as the one described before, a rational next step as well as a requirement for the next generations of cellular networks is the support of user personalization, application differentiation and quality adjustment based on the current communication scenario. User personalization is currently performed by some content providers, who distinguish among gold/silver/bronze users, based on subscription profiles, and configure the offered quality accordingly. However, explicitly paying for a subscription profile and, thus, receiving correlate quality is just one possibility of enabling QoE personalization. Moreover, telecom operators do not really engage in such a differentiation on a per-user basis, at least for the time being.

Furthermore, if we move one step further, we could look into QoE not only as a single MOS value, but more generally as an overall "experience package". For instance, we could easily claim that a user is not only interested in receiving the best quality, but may be equally (or more) interested in reducing the battery consumption of his/her device, in minimizing the charges imposed when using a service, in being prioritized for a specific task with respect to another, in being served in the securest way possible, or in combinations of all of the previous.

Capitalizing on this observation, we may envision future architectures, where the network tries to build "experience packages" based on actual communication scenarios and user profiles. We assume that such profiles may be built based on the users' communication habits, mobility patterns, physical

environment, used equipment, etc., and we might expect that a group of users will fit a specific profile. Once such a "pool of profiles" is deduced and becomes available at the operator's side, then configuring (i.e. tuning) the offered "experience package" during any communication session is a 4-step process:

- **Step 1:** Match a user to a suitable profile based on demographics, preferences, subscription types or other factors that are meaningful and measurable;
- **Step 2:** Derive the application/service unique characteristics and requirements, such as tolerability and adaptability to various network conditions, etc.;
- **Step 3:** Deduce the context of the current communication session (based on insights from the past, sensed environment, device info, etc.), where by context we refer to "any information that can be used to characterize the situation of an entity" [7];
- **Step 4:** Finally, build "experience packages" when delivering a service. This decision is inevitably a compromise between the requirements derived from steps 1-3 (i.e. demand) and the actual capabilities of the network (i.e. supply).

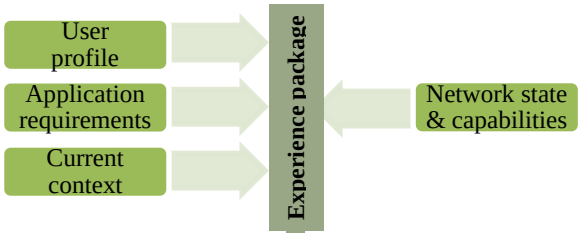

Figure 4 – The process of building an experience package.

In other words, as it is also depicted in Figure 4, a network's decision on how to build an experience package is a function of i) the user profile, ii) the specific application requirements, iii) the current context, and finally, iv) the current network state and capabilities. The latter includes any restrictions or limitations in the network, such as resource availability, current load, energy constraints, operator policies, etc.

As an example, we consider experience packages as a weighted sum of the following three dimensions: $\{QoE, price, battery\ level\}$, while this sum is subject to the actual network capabilities, i.e. $\sum_{i=1}^{3} weight_i * dimension_i \leq network\_specific\_value$.

In Figure 5, we then abstractly present five different experience packages that derive from matching these three weighted dimensions to the actual network capabilities (note that, for simplicity, context and application awareness are ignored here). We can then observe various possible network decisions: Delivering the experience package "1" will put more emphasis (weight) on QoE, so it may represent a situation where a user is mostly interested in the quality he/she receives, regardless of the price- or energy-to-pay. Similarly, packages "2" and "3" may represent users who care more about charges and energy costs when using a service, respectively, at the expense of quality. Finally, packages "4" and "5" imply some trade-offs between the aforementioned dimensions, subject to the currently restricted network resources.

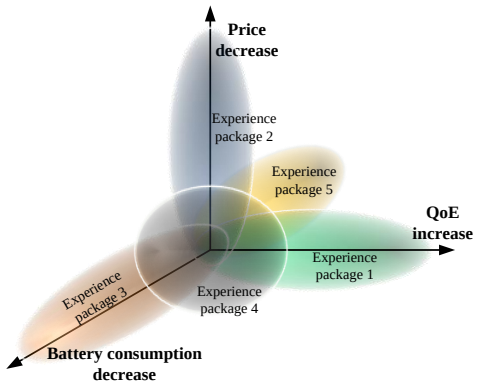

Figure 5 – Possible configurations of experience packages.

4. Context-based QoE provisioning

If we now revisit the high-level architecture described in Figure 2 by also considering context awareness (Step 3 in the previous section), then each component of the QoE provisioning chain is enriched as follows:

QoE-Controller: This entity now has to synchronize the collection of context-related information too, by requesting and accepting relevant input from various network entities and in various ways (sensors, user databases, device battery information, etc.).

QoE-Monitor: Novel context-aware QoE models need to be devised that are able to accurately measure and predict QoE under a specific context of use, e.g. [8].

QoE-Manager: This entity now has to take decisions that are also influenced by context-awareness. Also, it can actualize these decisions exploiting the current context (e.g. cache some videos based on popularity).

To demonstrate the potential impact of such context-driven decisions, we present a few examples:

1) Say a cellular network is aware that two users are in proximity based on GPS data. Then, any call initiated between them is automatically treated as a D2D connection, leading to smaller setup delays as well as to the avoidance of redundant control messages.

2) Say a user has limited battery, and this information becomes available to the network. Then a connection will be preferably switched to the closest access point (e.g. to Wi-Fi instead of a cellular access point, assuming collaboration between these access networks).

3) Finally, say a user checks his/her Facebook account at more or less the same time every day. So, the network may pre-fetch Facebook data instead of waiting for the user to update them on demand.

5. Conclusions

In this paper, we have argued that the acquisition of QoE intelligence and the exploitation of this intelligence by telecom operators can be a very powerful tool in their hands, either for improving their customers' QoE or for increasing their networks' efficiency. On top of that, adding context awareness and user profiling seems to offer a great potential in the next generation of cellular networks, e.g. through the configuration and delivery of "experience packages".

Acknowledgements

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QoE-driven Management Schemes for Multimedia Services

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1. Introduction

According to Cisco's forecast [1], IP video traffic will reach 79 percent of global Internet traffic and traffic via mobile/wireless access will exceed traffic via wired access by 2018. This trend indicates an increasing popularity of Internet video services such as YouTube and Netflix, and people would prefer to watch Internet video using a mobile device, such as a tablet or a smart phone due to its convenience. This fast-growing, large amount of video traffic (from SDTV, HDTV to UHDTV) and consumers' desire for a better perceived user experience, or Quality of Experience (QoE) pose real challenges to content/service providers and network operators on how to deliver multimedia services to end users over the Internet and/or resource-constrained mobile networks with a satisfactory QoE. The QoE becomes one of the most stringent factors influencing the success of multimedia services (including existing, new and emerging ones) delivered over the Internet.

The Quality of Experience (QoE) management generally refers to any control and management approaches which aim to optimize an achievable QoE for multimedia services such as VoIP and video streaming over fixed and/or mobile networks. In the past, the QoE management relied mainly on the network Quality of Service (QoS) parameters, for example, to reach a target packet loss rate below 2 percent for an RTP/RTCP-based video service or a target end-to-end delay less than 150 ms and jitter below 30 ms for a VoIP application. These QoS related parameters are not directly linked with the perceived user experience or QoE, and it is difficult to judge how well the QoE is for a delivered service under certain network QoS settings. In recent years, many novel approaches have been proposed to assess, control and manage QoE efficiently and effectively for multimedia services [2]. For example, QoE-oriented management/control schemes aim to automatically control the video sender bit rate according to the available network bandwidth, and to efficiently and intelligently allocate mobile resources according to different user and service needs. These QoE-oriented management approaches differ from the QoS-focused ones in the sense that the QoE is brought into the management/control cycle directly in order to optimize certain QoE targets.

In this paper, we will first present a general approach to apply the QoE assessment model for QoE-driven management schemes for multimedia services. We will then discuss in detail an application of the QoE model in an LTE downlink scheduling scheme for multimedia services (e.g. VoIP and video streaming) and further demonstrate how the proposed QoE-driven approach can increase the number of users a mobile node can support when compared with existing scheduling schemes.

2. Application of QoE Model in QoE Management

Considering a media delivery chain from media generation to media consumption as illustrated in Figure 1, the QoE as quality experienced by an end user is affected by both encoding and decoding/display techniques at a media server or a terminal device, and the transmission channel or the network the media is delivered over. Even under the same encoding /decoding and network settings, different video content may have a different impact on the QoE. As shown in Figure 1, the QoE metric is predicted from network, server/terminal (encoding/decoding) and/or media content related parameters non-intrusively via the QoE modelling block. The predicted QoE could be used for the QoE management in controlling encoding, transmission and/or decoding processes to optimize the delivered QoE or achievable QoE to an end user.

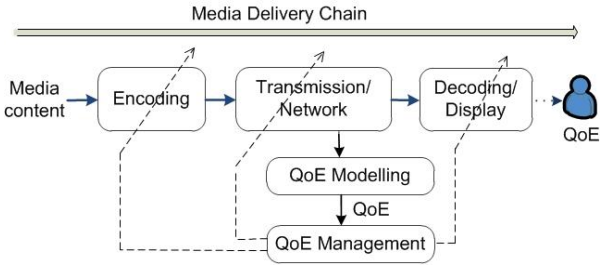

Figure 1: QoE Modelling and QoE Management

In QoE modelling, the network/transmission parameters may include average packet loss rate (PLR), mean burst loss length, delay variation (jitter) and delay. The server/terminal related parameters may include codec type (e.g. PCM or AMR for speech and H.264 or H.265/HEVC for video), quantization parameter (QP), sender-bit-rate (SBR), frame-rate (FR) and/or resolution for video, Forward Error Correction (FEC), concealment mechanisms and jitter buffer algorithms used in the server/terminal. The content

parameter refers to video content type which could be classified to a fixed number of types (e.g. three types for fast, medium and slow moving video contents). A general QoE model can be expressed by Eq. (1) and a simplified video QoE model is presented by Eq. (2) [3].

$$QoE = f(network, terminal, content) \quad (1)$$

$$QoE = \frac{\alpha + \beta FR + \delta \ln(SBR)}{1 + \mu(PLR) + \sigma(PLR)^2} \quad (2)$$

where the coefficients (e.g. α and β) are video content dependent.

It has to be noted that Eq. (1) has only considered technical related parameters along the media delivery chain which may have an impact on QoE. Non-technical related parameters such as user preferences, environmental impact or context (e.g. whether the media content is consumed in an office, at home or on a bus), and business impact (e.g. whether the service is offered free of charge or at a premium-rate) which may have an impact on the QoE are beyond the scope of this paper.

In our previous work, we have demonstrated the use of the QoE model in HTTP-based adaptive video streaming services which could be applied to MPEG Dynamic Adaptive Streaming over HTTP (DASH) schemes. The proposed approach is able to automatically and adaptively select a video segment at certain sender bit rate which can provide an optimized or a satisfactory QoE based on the current estimated network bandwidth and playout buffer status at the terminal [4]. We have also applied the QoE model, together with relevant network QoS parameters in a QoE-driven video sender bit rate adaptation scheme for video streaming over UMTS networks based on RTP/RTCP protocols [5]. QoE-driven adaptation schemes in [4] and [5] have both demonstrated more stable, optimized and satisfactory QoE under changing network conditions when compared with other non-QoE-driven approaches.

The QoE model has also been used in a power-driven VoIP quality adaptation scheme for video call over WLAN networks [6], where an acceptable QoE could be maintained by automatically changing video sender bit rate in order to conserve power in mobile devices and hence, prolong a VoIP communication session. The power saving between 10 – 30% of the total system power was achieved when the QoE-driven power saving approach was taken.

3. QoE-driven LTE downlink scheduling

Due to limited mobile network resources, it is always a tradeoff between the QoE delivered over mobile networks and the number of users a mobile node can support. Existing work on LTE scheduling are focused mainly on optimization of QoE for a fixed number of users (e.g. maximization of a sum of QoE for all users) within the limited network resources. In this section, we present an algorithm for LTE downlink scheduling to optimize the number of users a mobile node can support subject to satisfactory QoE achievable for all users. This approach is particularly useful in emergency mobile communications or at major events (e.g. a favorite sport) where it is crucial to increase mobile capacity and at the same time to meet satisfactory QoE for all mobile users.

Figure 2 depicts a conceptual diagram of QoE-driven LTE downlink scheduling where an eNodeB allocates available mobile network resources, in terms of available Resource Blocks (RBs), to mobile users according to received channel information (Channel Quality Indicator, CQI) from mobile users, network QoS (e.g. delay and PLR) and predicted QoE for mobile users for specified services at eNodeB.

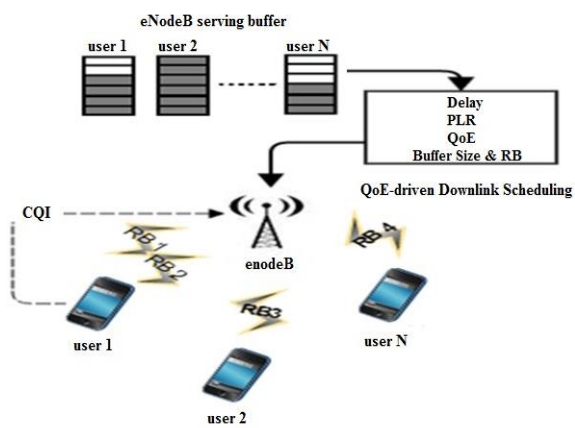

Figure 2: QoE-driven LTE scheduling

The LTE scheduler at eNodeB controls the allocation of RBs between mobile users at each transmission time interval (TTI) of 1ms. Assume a mobile network contains *M* eNodeB and each node can support up to *N* mobile users. The QoE-driven scheduling becomes an optimization problem to maximum the number of users which *M* mobile nodes can support subject to satisfactory QoE achievable by all users.

Let $d_{ij}(t)$ be the head of line (HOL) packet delay for user i at cell j at current scheduling instant t. $p_{ij}(t)$ and $b_{ij}(t)$ denote as the packet loss rate and the occupied buffer size for user i at cell j at time t. $RB_j(t)$ is the number of good available RBs at cell j at time t. The constraint of this algorithm is that the received $QoE \geq QoE_{min}$ (we assume $QoE_{min} = 3.5$, or MOS of 3.5 which is widely used in telecommunications world for an acceptable quality for services such as VoIP). The optimization problem is to maximize the

number of users for a given number of cells based on Eq. (3) subject to Eq. (4) and Eq. (5).

$$\max_{T} \sum_{j=1}^{M} o_j \quad \text{for } j = 1, \ldots, M \tag{3}$$

$$subject\ to:\ QoE_{ij} \geq QoE_{min} \tag{4}$$

$$\sum_{i=1}^{N} RB_{ij}(t) \leq RB_j(t)_{\max} \tag{5}$$

Where o_j denotes the number of mobile users for node j, T is the total time for resource allocation, and QoE_{ij} represents QoE achievable for user i at node j ($i = 1, \cdots N; j = 1, \cdots M$). $RB_{ij}(t)$ is the RBs allocated to user i at cell j at time t. $RB_j(t)_{max}$ is the maximum accessible resource blocks at cell j at time t.

An LTE scheduling algorithm for a single node case ($j=1$ and $M = 1$) for simplicity is illustrated below. Iteration process is carried out at every TTI.

Algorithm: LTE Scheduling

Input	Delay $d_i(t)$, PLR $p_i(t)$, buffer $b_i(t)$ for user i ($i \in [1, \cdots N]$) at time t
1:	Predict $QoE_i(t)$ and calculate the metric, $m_i(t)$ according to Eq. (6)
2:	If $QoE_i < QoE_{min}$, $m_i = m_i + 1$; or else $m_i = m_i$
3:	Schedule a user with the highest metric the required RBs matching to its buffer size $b_i(t)$
4:	Check for remaining RBs and schedule the resource to the user with the 2nd highest metric
5:	Repeat Step 4 until the TTI end.

Where:

$$m_i(t) = \frac{u_i(t)}{v_i(t)} \cdot d_i(t) \cdot p_i(t) \tag{6}$$

And $u_i(t)$ and $v_i(t)$ are accessible throughput and average achieved throughput for user i at time t, respectively.

4. Simulation Environment and Results

The simulation scenarios for a single-cell were implemented in LTE-Sim [7]. User mobility was set as a random way-point model [8][8]. The following table summarises the parameters used in the simulation.

Parameter	Value
Simulation length	180 s
Number of Cell	1 eNodeB
Cell layout	radius: 1 KM
Number of users	10 to 100 at the increment of 10
User speed	3, 30 KM/H
Traffic model	Real-time flows: H.264 for Foreman video trace at 242 Kbps and G.729 VoIP. Best effort flows: infinite buffer

The performance of the QoE-driven scheduling algorithm was evaluated and compared with that of MLWDF [9] and EXP/PF for both VoIP and video flows. The QoE metric (in terms of MOS) for VoIP was measured using the QoE model derived from packet loss and delay [10][10]. The video QoE was evaluated using the mapping between SSIM and MOS as described in [11][11]. The results are illustrated in Figures 3 and 4. The QoE-driven algorithm improves the overall cell capacity by the number of users with satisfactory QoE (satisfied users). In terms of VoIP flow, it increases the number of satisfied users by 75% compared to MLWDF in both user's speeds. While for video flow, the user's speed seems to have more impact on the cell capacity. The QoE-driven algorithm has enhanced the cell capacity by 30% for satisfied users at 3 KM/H speed when compared to the other two algorithms.

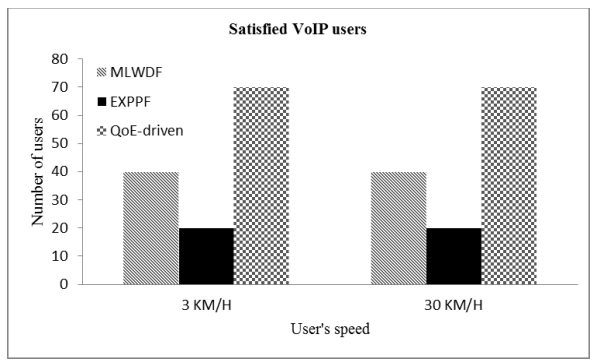

Figure 3: Satisfied VoIP users

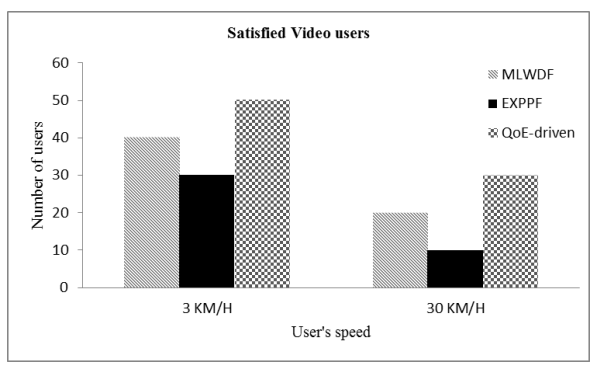

Figure 4: Satisfied Video users

5. Conclusions

In this paper, we presented a general approach to apply a QoE model in QoE management schemes for multimedia services. We also discussed an application of the QoE model in the LTE downlink scheduling to optimize QoE in terms of maximizing the number of users a mobile node can support while maintaining acceptable QoE for the mobile users.

Although QoE-driven management schemes have been proved to be effective in several multimedia applications, there are still many unsolved problems/issues which need to be addressed and investigated further by the multimedia QoE community. For example, how to predict and control QoE effectively and efficiently in rapidly changing network conditions; how to predict and manage QoE for new and emerging multimedia services such as mobile HDTV and online gaming; and how to achieve an overall end-to-end QoE optimization instead of segmented optimization focusing on one or two elements (e.g. encoding or network) over a complex system/network (such as the today's Internet).

Acknowledgement

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QoE-Aware Routing for Video Streams

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1. Introduction

In recent years, network operators have faced a rapid growth in the amount of data traffic on the backbone networks. This expansion is largely attributed to the rise of new usages such as multimedia streaming or live video watching. The "Global Internet Phenomena Report: 1H 2014" reported that multimedia streaming continues to be the largest traffic category on virtually every network [1]. In particular, this report reveals that multimedia streaming is the key driver of network growth and it is responsible for over 59% of wired network usage during peak period in North America. Furthermore, according to Cisco forecast [2], IP video traffic will account for up to 80% of all consumer Internet traffic in 2018, up from 66% in 2013.

To cope with this increasingly demand for bandwidth, network operators can either deploy new resources or improve the use of their existing resources. Investing in more bandwidth poses large capital and operational expenditures, therefore network operators may be more inclined to improve the actual configuration of their network by implementing congestion control strategies to enhance the quality experienced by the end-users (Quality of Experience – QoE) while at the same time avoiding the over-provisioning of transmission links. Congestion control offers a wide spectrum of policies to prevent congestion and performance collapses. Possible options include network provisioning, traffic-aware routing, admission control, traffic throttling and load shedding. In this paper, we focus on traffic-aware routing, in particular on the introduction of QoE-awareness for accounting for the users' perception when making routing decisions.

Traffic-aware routing is a mechanism used to make adaptive routing decisions with regard to the current utilization level of the network resources. The goal in taking bandwidth into account when computing routes is to shift some flows away from the heavily used paths where congestion will first occur. Traffic-aware routing aims at satisfying the QoE requirements expected by end-users by providing a sufficient level of Quality of Service (QoS) on each communication link, which is of utmost importance for delay-sensitive applications (*e.g.*, Telephony over IP) and resource-intensive applications (*e.g.*, streaming video).

This paper introduces a novel traffic-aware routing approach based on real-time estimates of the QoE observed by the end-users. By taking the QoE into account in path selection, better performance (in terms of QoE vs. link occupation) can be achieved. Our QoE-aware routing approach monitors the network conditions and dynamically makes adaptive routing decisions based on predictions of end-user perception of video quality. This video quality is quantified by Mean Opinion Score (MOS). More specifically, our approach consists of three main stages: collecting measurements on the on-going traffic over the communication links; (ii) modeling level, which is automatically performed; (iii) making adaptive routing decisions based on a perceptual video quality estimation performed in real-time.

In our analysis, we run extensive simulations using real traffic traces to assess the behavior of our QoE-aware routing approach. The experimental results show that our proposed approach leads to a good trade-off between the QoE expected by the end-users and resource utilization.

The remainder of this paper is structured as follows. Section 2 discusses the state of the art on traffic-aware routing solutions. In Section 3, we describe our QoE-aware routing approach. Section 4 presents simulation results illustrating the performance of our approach. Finally, Section 5 concludes this paper.

2. Related Work

Existing routing schemes in today's IP networks primarily focus on connectivity and only support best-effort service. These schemes are designed to cope with changes in topology, but not to changes in bandwidth and service quality. They are well suited for data applications (*e.g.*, FTP and Telnet), but were not designed to support many emerging real-time applications such as streaming video. Furthermore, the shortest path routing paradigm used in the current routing protocols such as Open Shortest Path First (OSPF) [3] may result in a load unbalance phenomenon where network traffic is overly concentrated on some links. In addition, it may also yield to excessive packet delays and exceedingly high levels of packet losses. Many studies of traffic-aware routing have been conducted in the literature to address the above issues, *e.g.*, [4,5]. These solutions are generally categorized into two different techniques. The first is source-based routing, in which there can be multiple available paths from a source to a destination, *e.g.*, [4]. The second one is based on a distributed

routing scheme, in which routers take charge of the multi-path function by controlling the shift of traffic across routes. This latter idea goes back to *Gallager* [6]. Most of the proposed solutions rely on a routing algorithm that includes a test operation, whose outcome decides how to select the optimal path among network routes. This optimal path is often related to the issue of QoS routing, which consists in finding a route between a couple of nodes that meets a series of QoS requirements such as end-to-end delay, packet loss, and other parameters. Overall, despite the variety and the number of proposed solutions, virtually all of them, if not all, are hampered by the difficulty to define the exact and complete expression of the user QoS requirements [7], so as to establish a correct trade-off between resource utilization and the satisfaction of users. Depending on the application, acceptable perceived quality can be achieved even if the QoS metrics are not so good [8]. By adopting QoE to the routing algorithm, better resource utilization can be achieved while, at the same time, respecting a given target in terms of the QoE expected by the end-users. We believe that a possible means to enhance these solutions is to include QoE requirements in their routing algorithms. To the best of our knowledge, very few works focus on QoE-based multi-path routing, *e.g.*, see [9]. In an attempt to address the research gap, we introduce a novel QoE-based routing approach for video streams.

3. QoE-Aware Routing Approach

Our QoE-aware routing approach consists of three main stages: monitoring, modeling, and routing decision.

Monitoring level

The monitoring level performs measurements on the on-going traffic and delivers three measured metrics: the packet arrival rate, the packet loss rate, and the packet loss burstiness, denoted by X, LR and $MLBS$, respectively. This latter metric is measured on a sliding time window of length 4 seconds. However, the first two metrics are computed over a short period of time, say, every 200ms.

Modeling level

The modeling level starts by characterizing the current evolution of LR as a function of X. More precisely, we intend to find a single approximate law that fits with the measurements. We denote this latter law by Q so that $LR = Q(X)$.

To do this, we used the method proposed by *Ammar et al.* [10]. We automatically discover a queueing model that reproduces as well as possible the behavior of each transmission link within an ISP network. In our work, we consider a single server queue model with a finite buffer space, namely, the *M/G/1/K* queue. Note that, Q needs to be regularly updated (say, every 20 seconds) in order to take into account the actual variations on the traffic conditions.

The discovered queueing model Q plays a key role in predicting the expected loss rate among each link of a routing path. Let $\overline{LR}_P^i$ be the expected value of packet loss rate at the ith node in the path P under the hypothesis of a new incoming flow, with a peak rate r, is directed to this path. Then using our approximate law Q we have:

$$\overline{LR}_P^i = Q_P^i\left(X_P^i + r\right)$$

where X_P^i reflects the throughput of the on-going traffic at the ith node in the path P, and Q_P^i defines the evolution of $\overline{LR}_P^i$ against the throughput X_P^i.

It follows that, in order to implement the QoE-aware routing, we need to be able to accurately estimate the perceived quality of the video streams, in real-time. To do this, we use the Pseudo-Subjective Quality Assessment (PSQA) approach presented in [11]. Briefly, PSQA allows for the creation of parametric QoE models, usually mapping QoS and application-layer parameters to the measures of perceptual quality, typically MOS values. The mapping can be implemented with a variety of statistical learning tools.

The PSQA estimator used in this paper is a simplified version of the one proposed in [12], in which one of the application-layer parameters is fixed to a medium value, and the resolution is chosen among a possible set of values according to the observed bit rates (in the examples described below, the resolution is fixed, but in actual usage, it could be estimated in real-time from the observed traffic). The model used considers four inputs, namely, the aforementioned video resolution and quantity of movement, and the loss process in the network, characterized by the loss rate and the mean loss burst size. Therefore, the PSQA estimator becomes:

$$\overline{MOS} = F(RES, QM, LR, MLBS)$$

where RES can be estimated from the observed bit rate for the flow, QM is fixed, $MLBS$ is measured from the network, and LR is derived from the queueing model as described above.

Routing Decision

Finally, the routing decision can be formalized as: a new incoming video is directed to the path P if

$$\overline{MOS}_P \geq T_{mos}$$

where $\overline{MOS}_P$ corresponds to the minimum MOS value encountered along the path P, and T_{mos} represents the MOS threshold. Otherwise, this flow will be redirected to another path that fulfills this latter condition. Note that, when there is no alternative path with acceptable MOS, we forbid this flow from entering the network

since the available networking resources are deemed insufficient.

4. Numerical Results

Description of the scenario

The network topology of our experiments is shown in Figure 1. The capacities of the links are equal to 10Mb/s. The size of each buffer is set to 20ms and the queueing discipline is FIFO (*First In First Out*).

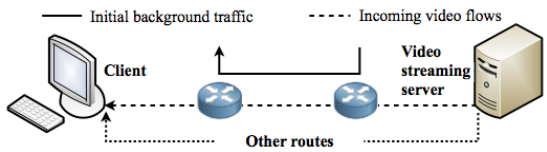

Figure 1. On-going traffic conditions over the network

We evaluate the performance of our approach using the discrete-event simulator ns-3. Each simulation is run for a period of 10 minutes.

It is also worth nothing that we benchmark our approach against an *oracle*, which represents an unrealistic traffic-aware routing solution. This oracle accepts the maximum number of videos over a routing path, thus achieving the maximum workload, while successfully meeting the QoE target.

The on-going traffic consists of two components. A background traffic that is not subject to any traffic-aware routing control. We represent this background traffic by a real traffic trace [13]. In our experiments, we adjust this trace by scaling it down such that its average rate of transmitted packets is equal to 4Mb/s. In addition to this background traffic, the on-going traffic is also composed of incoming video flows that requests access to the network. Each incoming video is represented by a real MPEG-4 video trace. The statistical properties of the generated video traces are available at [14].

Video traces arrive randomly to the communication path according to a Poisson process with a constant rate equal to 0.18. Their durations are drawn from an exponential distribution with mean of 60 seconds. The average rate of the transmitted packets of the aggregated video traces is approximately equal to 0.28Mb/s.

Performance Evaluation

Figure 2 depicts the instantaneous behavior of our QoE-aware routing approach with regards to the MOS target, $T_{mos} = 3$. X-axis represents the elapsed time and Y-axis indicates the instantaneous MOS score. To begin with, Figure 2 shows that our proposed approach yields satisfactory results since it almost constantly meets the MOS threshold. It is also worth noting that it exhibits a behavior roughly close to the oracle. More specifically, our proposed scheme fulfills the MOS threshold around 97% of the time. This result highlights the ability of our QoE-aware routing approach to adjust its routing policy according to the actual variations on the traffic conditions.

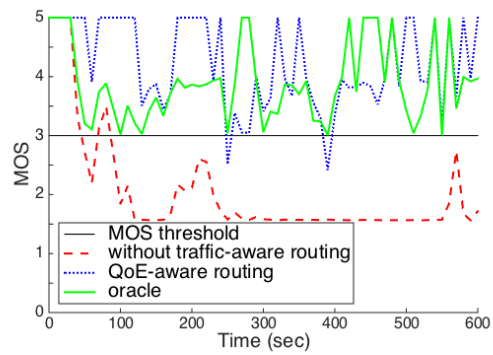

Figure 2. Instantaneous behavior of our QoE-aware routing approach

Finally, if no traffic-aware routing were to be performed, the results show that the MOS target is severely and almost constantly violated, typically around 73% of the time.

Table 1. Overall behavior of our QoE-aware routing approach

Routing approach	Utilization rate	Violation rate (in percent)
Oracle	0.58	0%
QoE-aware	0.55	9%
Inactive	0.76	73%

We summarize the performance of our QoE-aware routing approach in Table 1. Table 1 relates the following information: (i) network utilization rate; (ii) violation rate of the MOS threshold that represents the percentage of time during which the MOS threshold is violated. These metrics are computed over the entire duration of the simulation. The results show that the oracle leads to an average utilization rate equal to 0.58. They also indicate that our approach yields satisfactory results since it leads to a utilization rate (*i.e.*, 0.55) close to the one delivered by the oracle. They also imply that our approach fulfills the MOS threshold about 91% of the time. Finally, when the traffic-aware routing is inactive, the MOS threshold is severely violated (73% of the time).

5. Conclusions

In this paper, we presented a novel QoE-aware routing approach based on real-time estimates of the QoE observed by the end-users. This approach monitors the network conditions in real-time and dynamically makes adaptive routing decisions based on predictions of end-user perception of video quality. This video quality is quantified by Mean Opinion Score (MOS). More specifically, our approach consists of three main stages: monitoring, modeling, and routing decision.

We show through simulations using real traffic traces collected on real life networks, the ability of our QoE-aware routing approach to achieve a high level of utilization of the network resources, while providing a fair guarantee of the quality experienced by end-users. The experimental results show that our approach leads to a good trade-off between the QoE expected by the end-users and resource utilization. This ability stems from the automatic and quick adjustment of its routing policy according to the actual variations on the traffic conditions.

Acknowledgement

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The Economics of Quality of Experience: Recent Advances and Next Steps

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1. Introduction

Quality of Service (QoS) has been an active research topic in the networking community for more than three decades, resulting in a plethora of related research projects and publications[1]. Despite of these efforts, as of today, no large-scale rollout of a QoS-enabled Internet architecture has been successful, a fact that has led Crowcroft *et al.* already some years ago to the almost desperate comment: "Why this apparent waste?" [1]. In the subsequent analysis, at least two key reasons for this situation are identified: On the one hand, the authors point out that QoS research often lacks timeliness and/or proactivity with respect to the actual state of the art in networking technology, while, on the other hand, they argue that the implementation of mechanisms for quality differentiation on top of a network operating on a best effort basis poses an inherently difficult problem. Later on, R. Jain has claimed that it is the lack of a proper relationship between QoS technology and corresponding charging policies which is to be blamed [3], while more recently also an alleged general preference of Internet users for flat rate pricing schemes or even completely free access to Internet services has become popular as another potential factor significantly which could be responsible for the apparent difficulties of establishing quality differentiation in the Internet in a sustainable way.

In this article, we will discuss whether the recent conceptual transition from (network-centered) Quality of Service to (user-centered) Quality of Experience (QoE), which – by the way – we understand as a proper paradigm change rather than a mere switchover between buzzwords[2], could provide a fresh and different access to this problem. Therefore, in section 2 we briefly review the concept of QoE from a micro-economic perspective, while section 3 highlights the corresponding market and business perspective. A brief summary and conclusions are presented in section 4, before an outlook on current and future work completes our survey account on this highly interesting and yet still rather neglected interdisciplinary research field.

[1] For the period 1993-2002, [1] reports at total of more than 7,800 QoS-related publications; a similar number has been valid also for the subsequent decade [2].

[2] In order to underline the significance of this turn, we propose to term it an "*Anti-Copernican Revolution*", as it aims at putting the human being (user) back into the center of the (technological) universe, cf. [2].

2. Modeling the Micro-economics of QoE

While the (almost natural) idea of aligning the concept of service quality along the actual experience of the user (in the sense of *overall acceptability of an application or service as perceived subjectively by the end user* [4]) has already been proposed in 1994, only recently a broad understanding of the actual consequences has been achieved, leading for instance to the definition of QoE as *degree of delight of the user of a service* [5], which *depends on content, network, device, application, user expectations and goals, and context of use* [5]. More specifically, [6] provides a detailed classification of the corresponding influence factors with respect to the physical, temporal, economic, task, social, technical and information context. Based on this, [7] proposes an umbrella framework integrating a QoE model, a user state model and a user behaviour model, and includes a more detailed discussion of various context factors, among which economic context factors turn out to play an especially interesting role.

As far as these latter factors (and especially charging-related ones) are concerned, it is important to note that, for several reasons which are discussed in [8], it is not possible to use results of QoE trials for directly deriving a corresponding microeconomic utility function, despite of the natural closeness between both concepts. Nevertheless, it is instructive to briefly revisit some empirical evidence of end users' willingness-to-pay (WTP) when confronted with services that offer a variety of quality levels. Hence, Fig. 1 presents results from a user trial comprising more than 40 test subjects who were offered three videos of length 20mins each, where they could use the first five minutes to freely check available quality/price combinations before settling their final decision for purchasing one of the quality classes (for further details on the experimental set-up and additional results of the study we refer to [9]).

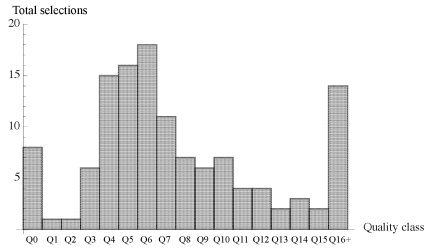

Figure 5 - Empirical Willingness-to-Pay (WTP) distribution for a video streaming service offering a total of 17 different quality levels

Note that during these trials, users have been given real money to deal with, in order to achieve outcomes close to reality. Moreover, the top quality classes Q16-Q19 actually offered identical quality for different prices, in order to allow for price discrimination. The depicted results can be easily interpreted as follows: while we observed quite a few test subjects going for either the worst=cheapest (Q0, i.e. price-sensitive "free riders") or the best=expensive option (Q16+, i.e. quality-sensitive "VIPs"), most of the participants went for a carefully balanced decision, taking their individual price/quality tradeoff into account. Moreover, if it comes to rising tariffs, we could distinguish three types of users: (1) those who tend to keep their overall expenses constant, (2) those who just don't care and are willing to pay more, and (3) those who simply go for the top price, as long as they are convinced to get top quality for it, which allows to apply price discrimination.

In order to better understand this user typology, we will now briefly sketch an extension of the theoretical fixed-point model initially proposed in [10]. Hence, consider a network with limited overall resources where users are offered a service of different QoS levels for different prices. Then, the case of a price-sensitive user corresponds to the model depicted in Fig. 2, where QoE is described as a function of both QoS and the price to be paid, while on the other hand price regulates demand, and demand itself is assumed to be the crucial parameter for the QoS level that can be offered by the network (see [10] for further details of this model of service quality in a network with finite resources). Under relatively mild assumptions with respect to monotonicity, slope and/or curvature (concavity vs convexity) of the functions $q(d)$, $x(q,p)$, $p(x)$ and $d(p)$, the existence of two fixed points can be demonstrated, i.e. an unstable (boundary) fixed point characterized by huge demand and low quality which is for free, and a stable (interior) fixed point as a result of an adequate balance between the price/quality tradeoff.

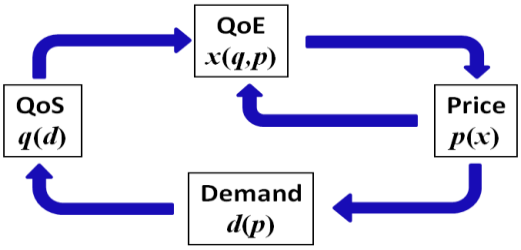

Figure 6 - Fixed-point model of a price-sensitive user

A similar model can be established for the case of a quality-sensitive user, see Fig. 3, where the demand function depends on two input parameters, i.e. QoE and price, while QoE is determined by QoS only, and the rest of the model stays unchanged.

Mathematical analysis reveals that, again under relatively mild conditions for the form of the functions $q(d)$, $x(q)$, $p(x)$ and $d(p,x)$, this system is driven towards a unique fixed point which is characterized by top quality at a top price (and corresponding low demand).

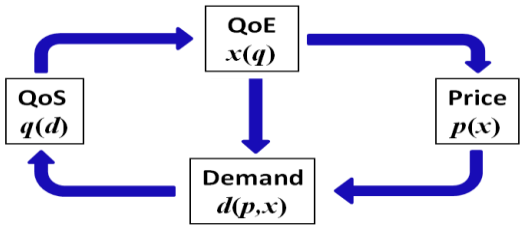

Figure 7 - Fixed-point model of a quality-sensitive user

Beyond these fundamental results, it is also interesting to note that model and reality match with respect to the way in which the respective equilibrium is actually attained. While the above models predict convergence in the form of a dampened oscillation (see [11] for an illustrative example), this is exactly what we typically observed also in our trial. For instance, Fig. 4 depicts the convergence behaviour of two typical test subjects (users #14 and #19; each user had been offered three movies in total, hence the three trajectories each) [10].

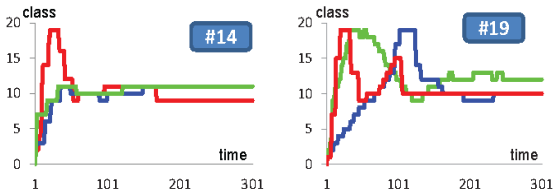

Figure 8 - Typical convergence trajectories towards fixed-point equilibrium (dampened oscillations)

Note that the final choices are relatively independent of the video content and determined by the individual quality preferences of the user. Especially from the trajectory of user #19, we may also observe that trial participants took their choice of quality levels quite serious: typically, test subjects used their initial five minute grace period to experiment with 10-50 different quality levels – sometimes even going up to 80 or more changes of quality levels (which means on average one new quality level each 3.5 sec) before eventually taking their final decision.

Hence, these results confirm our modelling approach presented earlier, which is based on the integration of charging and pricing as key influence factors into the general user context. At the same time, they also indicate that, at least in the context of our trials, users are indeed willing to pay for quality. Some implications of this fact will be discussed in the next two sections.

3. Business and Market Perspective

In the increasingly competitive telco market, service quality may have the potential to replace or at least complement tariffing as the key selling point crucial for sustainable economic success [12]. Hence, the paradigm shift from QoS to QoE might have a profound impact on the entire related value chain, for instance with respect to increasing customer loyalty and thus reducing churn. As an immediate consequence, [12] describes how to adapt Customer Experience Management (CEM) systems, which today massively rely on so-called Key Quality Indicators (KQI) that emerge as transformation of aggregated Key Performance Indicators (KPI). Instead, it might be appropriate to go for a per-user per-session granularity which is expected to allow for a much more concise mapping between performance data collected from the service and the corresponding subjective user experience.

In contrast, [13] and [14] aim at addressing the issue from an entirely different point of view, investigating conditions and strategies for a successful market entry in the age of QoE. Unifying demand and expenditure considerations with revenue optimization on the supply side, a comprehensive set of recommendations for optimal price and quality setting of new services is derived which turn out to be not necessarily unambiguous and sometimes even antagonistic, depending on the market scenario and the perspective applied. For instance, from a per-user perspective, Network Service Providers (NSPs) should not offer dumping prices at market entrance, while on the other hand such aggressive pricing allows for a progressive penetration of immature markets and thus might be an optimal NSP strategy, at least in the case of high competition [14].

Finally, progress has also been made if it comes to selling QoE to the end user. Here, following the well-established concept of Service Level Agreements (SLA) for settling various aspects of QoS-related contracts between providers and users, [15] proposes the analogous notion of *Experience Level Agreements* (ELA) for QoE-based contracts, taking the user-centric perspective on service quality into explicit account. While SLAs rely on the specification of relevant low-level network parameters, ELA will have to convey service performance in terms of suitable QoE indicators to which users may easily relate.

4. Conclusions, Open Issues and Challenges

In contrast to widespread assumptions, evidence from our trials demonstrates that and how *users are willing to pay for service quality*. Hence, the paradigm change from QoS to QoE leads to a closer link between differentiated quality and pricing, thus offering the potential to become a promising opportunity for eventually bringing quality differentiation into the networks.

Based on this, current and future research is primarily addressing the following open issues and challenges:

1. *Fundamental Laws for QoE*: While we have seen earlier that, for practical purposes, a per-user view on QoE might be more relevant than an aggregate one, it is nevertheless imperative to further improve our general understanding for the underlying laws of QoE, e.g. extending related work on the IQX hypothesis [16] or Weber-Fechner type models [17].
2. *Harmonization Issues*: As has become clear from the above discussion, there is still a need for harmonizing and integrating various QoE-related concepts. The distinction between utility functions and customer satisfaction as well as the transition from individual and situative quality ratings to more generic representations have been already mentioned in detail. Potential saturation effects may introduce additional non-linearities which further dissociate QoE from utilities and product sales. User satisfaction is furthermore inherently bound to specific services, situations and users. Without explicit evidence on WTP, comparing QoE ratings across services is not sufficient for gaining robust insight into the estimation of utility and expenditure data [8]. Future research also has to overcome the isolation of QoE results for individual tests, and to associate it to more monetary-oriented views. Finally, the end-to-end perspective of network quality requires a considerate balancing of user, technological and economic interests in integrated solutions, e.g. QoE- and WTP-aware network adaptation.
3. *Cognitive Dissonance Aspects*: As shown in [17], cognitive dissonance effects may provide an additional source of non-linearities between user experience and WTP. However, this important aspect requires a more detailed investigation, based on further extensive user trials.
4. *ELA Specification*: While the basic concept for ELAs is outlined in [15], there are still quite a few challenges left, including details on how to specify objective representations of QoE which are agreed upon by both users and providers (plus a suitable formal language), related mechanisms and metrics, a corresponding standard API, a viable monitoring architecture and an efficient marketing strategy for replacing the prevailing flat rate approaches.
5. *Network Neutrality:* Last, not least, another inherent market challenge for QoE originates from the protection of social values such as Network Neutrality and non-discrimination practices. While QoE may well support for increasing the customer satisfaction and achieve loyalty gains, the very dynamic and direct utilization of QoE without service- or user-awareness might require a further substantial change of the way of thinking in QoE research.

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INDUSTRIAL COLUMN: SPECIAL ISSUE ON COMMUNICATION NETWORKS FOR THE SMART GRID AND ELECTRIC VEHICLES

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Multimedia is an inseparable part of monitoring and surveillance in cyber-physical energy systems, a.k.a the smart grid. On the other hand, multimedia services, as much as any information and communication service, depend on reliable electricity supply and distribution. With the smart grid, power grid and Information and Communication Technologies (ICTs) are becoming related in intertwined ways. Adding up to this relationship, transportation is making its way through a long history on Vehicular Ad Hoc Networks (VANETs) and now with Electric Vehicles (EVs). Many challenges and opportunities emerge as new technologies become predominant in our daily lives.

This Special Issue focuses on the recent progress in smart grid and electric vehicle communications, and explores multimedia-rich dimensions. With contributions from globally renowned experts in the area and perspectives from diverse geographic locations, this Special Issue sums up genuine innovations in the smart grid area and layouts a roadmap for future opportunities.

In the first article titled, "*Big Data and Cloud Computing Based Demand-Side Management for Electric Vehicles in Smart Grid",* Ye and Qian from University of Nebraska – Lincoln present a cloud-based, big-data-driven electric vehicle load management system. With big data analytics, a service provider can have precise estimation of demand and consequently perform load scheduling and dynamic pricing. The work shows that when big data is used to derive estimations, decent peak to average ratios can be maintained although the load on the entire grid increases. The intertwined relation of multi-dimensional, multimedia data, big data analytics and their application in the smart grid bares invaluable opportunities for researchers.

Nyato from Nanyang Technological University and Hossain from University of Manitoba give a unique perspective on the mutual interaction of data communication network and the smart electricity grid. Their letter titled "On the Impact of Data Communication Reliability on the Optimization of Power Consumption in the Smart Grid Environment" analyzes the impact of reliability of the smart grid data communications on the optimization of power consumption. When connections from home area networks (HAN) and neighborhood area networks (NAN) are unavailable, the authors show that the scheduling policy becomes suboptimal, resulting in higher power consumption cost which emphasizes the significance of the health of the underlying communication infrastructure.

The third article from Granelli of University of Trento, Italy, "*Electric Vehicles and Fast Charging Stations: A Feasibility Study*" provides an overview on the usage of fast charging stations for electric vehicles. Queueing theory principles are applied to electric vehicle charging and fundamental relationships among the station's design parameters have been identified. Utility operators and charging station service providers can benefit immensely from the provided results.

The fourth article is *"A Wi-Fi-based Power Metering System for Energy Management and Controlling"*, from Cetinkaya and Akan at Koc University, Turkey. In this work, a new Wi-Fi based power metering gateway has been developed for demand side energy management and real-time control and monitoring of home appliances. Device recognition, mobility, re-energizing and chain delay challenges have been addressed. As a result, a more secure, accessible, mobile, controllable and versatile system has been achieved for the control of home appliances which is a sought after technology for appliance manufacturers as well as consumers.

Gerla from University of California Los Angeles provides pioneering thoughts on electric and autonomous vehicles, and their interaction with the smart grid. His letter titled "Electric and Autonomous Vehicles in the Smart Grid New Routing and Communications Requirements" draws attention to how taking application-specific requirements into account can result in huge performance gains.

The last article of this Special Issue is from Erol-Kantarci at Clarkson University, NY and Mouftah at University of Ottawa, Canada. The title of this letter is *"Electric Vehicles in the Smart Grid and Energy Trading Communities"*. This letter is based on the

authors' recent tutorial series titled "Communication Architectures and Networking for Electric Vehicles in the Smart Grid." Electric vehicles are considered as Mobile Energy Buffers (MEBs) which trade quantized energy blocks to Delay Tolerant Loads (DTL) in the smart grid communities. A token-based energy management system is empowered by a hand-shake protocol that advertises and matches tokens. The token-based energy trading mechanism can provide chunks of quantized energy to home appliances as well as to multimedia servers and carriers. Energy trading is a highly novel concept that is anticipated to grow and impact the future generations' electricity usage.

This Special Issue delivers recent progress in smart grid and electric vehicle communications while exploring opportunities for multimedia-rich applications that would strengthen the reliability of the grid. Finally, we would like to thank all the authors for their great contributions and the E-Letter Board for making this Special Issue possible.

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Big Data and Cloud Computing Based Demand-Side Management for Electric Vehicles in Smart Grid

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1. Introduction

Electricity load of the power grid fluctuates throughout a day. On one hand, conventional power generators are able to follow the load requirement, however the transition of power generation from peak load to off-peak load causes waste of conventional fuels [1, 2]. On the other hand, renewable energy resources cannot keep up with the fluctuation of load requirements. Smart grid is the next generation power grid with two-way communication networks [3, 4]. Because of the vast amount of timely information exchanged between the customers and service providers, demand side management (DSM) can be applied so that power load of the grid can be smoothed. A smoother power load, or a lower peak-to-average ratio (PAR) helps to reduce waste of conventional fuels and emission of greenhouse gas. As electric vehicles (EVs) taking more share of the market, it will cause a significant load increase to the power grid. For instance, if EVs have 30% market share in the US, then the load increase would be around 18% of the US summer peak load [5, 6].

In this work, we propose a DSM including EVs so that the increased power load can be applied to smooth the entire power load of the grid instead of adding burden to it. In our proposed DSM, EVs are assumed to be equipped with standardized batteries so that the customers can switch them at battery exchange stations (BESes). Compared with charging EVs directly, BESes have more flexible charging schedules so that DSM can be better integrated. However, to achieve DSM even with BESes, much information is needed in both ways. On one hand, a BES needs to know the number of customers to serve in a time slot, electricity price for the time slot. On the other hand, service provider needs the amount of electricity requirement from the BESes to have a precise estimation of the grid load and generate smart pricing accordingly.

We propose to establish a cloud based, big data driven communication system for information gathering and extraction. Nowadays, vehicles (including EVs) are getting smarter with lots of sensors, microcomputers, and communication capabilities. The status (e.g., location, anticipated destinations, remaining energy, distance to go, etc.,) of a vehicle can be monitored thoroughly. With the permission of the owners, BESes and service provider could have huge amount of data. With big data analytics, a service provider will be able to have precise estimation of energy requirement, BESes will be able to do load scheduling according to smart pricing. Assuming that the communication system and big data analytics work properly, we show that the introduction of EVs increases the efficiency of the power grid by lowing the PAR in spite of load increase for the entire grid.

2. Cloud Computing and Big Data Driven Communication System

Since smart cars have advanced communication capabilities, and most customers have smart devices (e.g., smart phones and tablets) which can connect to smart cars in various ways (e.g., bluetooth in car and cellular networks otherwise), we propose a cloud computing and big data driven communication system, as shown in Fig. 1.

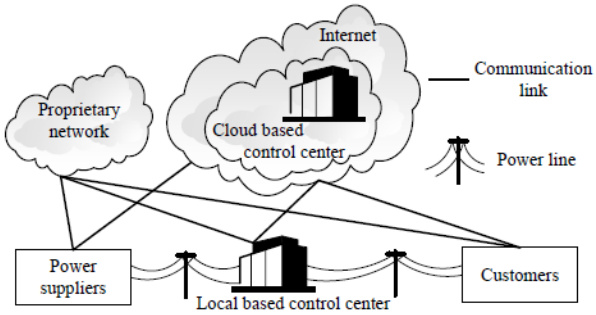

Fig. 1. Communication infrastructure in smart grid.

The proposed system has both proprietary network and internet. It is expensive to deploy and maintain proprietary networks, therefore, only a portion of the communication in smart grid is achieved by such proprietary networks. For instance, transmission line monitoring network in remote areas, advanced metering infrastructure which carries lots of privacy of the customers, etc. Smart meters at the customer side are assumed to communicate with service provider through proprietary networks. Public networks (i.e. internet) are responsible for some other purposes of the communication. Moreover, customers with smart devices will be easier to browse the internet compared with connecting to propriety networks. For example, checking smart pricing and remote control smart

appliances from a laptop. In between power suppliers and customers sits control center, which consists of both local based and cloud based database and control centers for data gathering and data processing.

In general, local control center is responsible for real-time and sensitive data gathering and processing. Local control center is distributed throughout the power grid for reliability and scalability. Cloud based control center is responsible for the gathering and processing of big data, non-sensitive data, and pre-processed data from local control center. Cloud based control center will extract information for better prediction and estimation of power consumption as well as renewable power generation. Such information will be fed back to local control center for further processing and distribution to the customers. In the DSM considering EVs, customers let the database gather various statuses such as real-time locations, battery status. Cloud based control center run big data analytics and model the life style of the customers (e.g., driving schedules). Based on that, precise estimation of incoming customers of a certain BES can be made for a time slot. BESes will schedule the charging/discharging based on the number of incoming customers and smart pricing of that time slot. Smart pricing is calculated at local control center based on the load requirement precisely estimated from the big data in cloud based control center.

3. Preliminary Analysis of DSM with EVs

In this section, we assume that the cloud based and big data driven communication system operates properly, all the customers are willing to participate once they see the benefits. Therefore, we have precise estimation of customers and load requirement. The preliminary analysis shows the positive impact caused by the increasing load brought by EVs.

Let S = $\{s_1,s_2,...,s_N\}$ be the set of all BESs, and N , |S| BESes in total. Each BES is equipped with m_i fast charging/discharging ports (e.g., DC fast charging, 600-volt). The BESes do not provide ports for customers to directly charge the PHEV. Let A be the set of all PHEVs, and let A , |A| be the total number of PHEVs. Moreover, we consider a daily model in this work without loss of generality. Let each day be divided into several uniform time intervals, denoted as T = $\{T_1,T_2,...,t_T\}$.

Without loss of generality, we assume that there is one type of standard batteries. It is intuitive to extend the model to multiple size batteries depending on the types of vehicles. Battery exchange is done at a *flat rate* p_0 per exchange. For simplicity, we assume that the state of charge (SoC) of the batteries is a constant (e.g., 15%). If a BES sells back the electricity to the grid, it discharges a fully-charged battery to 15% as well. Besides earning profits by exchanging batteries, each BES also makes profits by participating in DSM system with smart pricing mechanism. Each BES is willing to sell back the electricity to the power grid during peak hours because the price is higher, and to charge the batteries during off-peak hours. The smart pricing function is considered convex and increasing, and it is generally adopted as a quadratic function [1, 2], i.e.,

$$c(l) = al^2 + bl + c, \tag{1}$$

where a, b, c are constants. Note that l in Eq. (1) is the total load of the power grid.

For simplicity, we assume that the distribution of incoming customers at BESes follows the pattern of departure and arrival of the customers at home, which follow two normal distributions with the mean of 7 a.m. and 6 p.m. and a standard deviation of 1 hour, respectively [7, 8]. The distributions are expressed as

$$p_d = \frac{1}{\sigma\sqrt{2\pi}} \exp \frac{-(t-\mu_d)^2}{2\sigma^2}, \tag{2}$$

$$p_a = \frac{1}{\sigma\sqrt{2\pi}} \exp \frac{-(t-\mu_a)^2}{2\sigma^2}, \tag{3}$$

where $\sigma = 1, \mu_d = 7$ and $\mu_a = 18$. Since a customer only need to exchange the battery once, we adopt $0.5p_d$ for the customers come during the departure window, and $0.5p_a$ for the customers who come during the arrival window. Note that the estimation of incoming customers could be more precise based on real big data analytics.

The ultimate goal of DSM is to minimize PAR. Let $l_i(t) = l_i^+(t) - l_i^-(t)$ be the electricity load at s_i during time slot t, where $l_i^+(t)$ is the load selling back to the grid, $l_i^-(t)$ is the load buying from the grid, $n_i(t)$ is the number of cars for battery exchanging. Note that $l_i(t)$ can be negative. Without loss of generality, we assume that the total load of the grid is always positive. The proposed DSM is shown in Eq. (4).

$$P1: \min \frac{\left(\sup_{t\in T}\left(\sum_{i=1}^{N} l_i(t)\right)\right)}{\frac{1}{N}\sum_{i=1}^{N}\sum_{t=1}^{T} l_i(t)}, \tag{4}$$

s.t.

$$l_i^+(t) \le l_{max}^+ \cdot m_i, \tag{5}$$

$$l_i^-(t) \le l_{max}^- \cdot m_i, \tag{6}$$

$$l_i^-(t) \le l_0 \cdot b_i(t), \forall \mathrm{t} \in \mathrm{T}, \tag{7}$$

$$\sum_{i=1}^{N} b_i(t) \ge \sum_{i=1}^{N} n_i(t), \forall \mathrm{t} \in \mathrm{T}, \tag{8}$$

$$\sum_{i=1}^{N}\sum_{t=1}^{|T|} l_i(t) \ge \sum_{i=1}^{N}\sum_{t=1}^{|T|}\left(l_0 \cdot n_i(t)\right) = l_0 \cdot A, \tag{9}$$

Eq. (5) indicates that the total amount of electricity buying from the grid cannot exceed the charging capacity of the station during t_i. l_{max}^+ is the maximum charging electricity load for one outlet. Eq. (6) indicates that the total amount of electricity sold back to the grid cannot exceed the discharging capacity of the station. l_{max}^- is the maximum discharging electricity load for one outlet. Eq. (7) indicates that the total amount of electricity sold back to the grid is also bounded by $b_i(t)$. Because of precise estimation from big data analytics, Eq. (8) ensures that the overall fully

charged batteries are enough for all the customers. Finally, Eq. (9) indicates that the total surplus electricity bought from the grid should exceed the total need of the PHEVs. P1 is a convex optimization problem which has a unique optimal solution.

Assuming that there are 10 identical BESs in town. Each BES has $m_i = 20$ charging ports and starts with 20 fully charged batteries. A total of $A = 500$ EVs to be served daily. Each battery has a capacity of 10 KWh. Each charging port at BES charges a battery at 17 KW per hour with 100% efficiency and discharges a battery at 8.5 KW per hour with 100% efficiency. Let $|T| = 24$ so that each time slot lasts for 1 hour. Let the existing load of the power grid have off-peak hours span from 0 to 8 and from 19 to 24, and peak hours span from 9 to 18. The load in each time slot fluctuates randomly while following the trend of peak/off-peak hours. Moreover, we let the total load needed by PHEVs be exactly 18% of existing load in power grid. Note that the settings are subject to change based on further big data analytics before actual deployment of BESs.

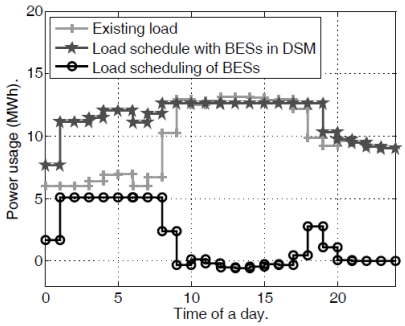

Fig. 2. Smoothed load with BESs.

As shown in Fig. 2, we can see that although the total daily load of the power grid increases by 18%, the peak load is reduced, and thus the load schedule is further smoothed and the PAR is reduced. One important observation is that the new load schedule has different pattern of peak/off-peak hours. For example, mid-night hours are peak hours in the new load schedule after participation of BESs. It is because BESs sell back the electricity to the grid during previous peak hours and charge during previous off-peak hours. Therefore, predetermined pricing schedule based on peak/off-peak hours may not be reasonable.

4. Conclusion

In this paper, we propose a cloud based and big data driven demand side management system considering EVs in smart grid. Although EVs will introduce a significant load increase to power grid, DSM will be able to lower the PAR and make the power grid smoother and more efficient if precise estimations can be made. Our future work will focus on realizing the communication system to achieve precise estimations.

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On the Impact of Data Communication Reliability on the Optimization of Power Consumption in the Smart Grid Environment

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Abstract
Data communications infrastructure plays an important role to communicate information (e.g., related to power generation, supply, consumption) among the various elements in the smart grid. In this letter, excerpted from [1], we consider the reliability of the smart grid data communications infrastructure and its impact on the optimization of power consumption in the smart grid environment. For optimizing the power consumption, we consider a deferrable load scheduling method which is modeled by using a constrained Markov decision process (CMDP) model, taking into account the unavailability of the home area network (HAN) and neighborhood area network (NAN) gateways.

1. Introduction

With advanced data communications technologies, the smart grid is emerging as the future power system which can operate in a cooperative, responsive, economical, and organic manner. One of the most important features of the smart grid is the meter data management system (MDMS) that collects, exchanges, and processes the meter data with an objective of minimizing the power consumption and supply costs. The MDMS can implement a demand response (DR) program through real-time pricing mechanism. The time-varying price can motivate the consumers to defer their power consumption to the off-peak period. Also, the MDMS can utilize power demand and supply information transferred from the consumers and distributed energy resource (DER) for the economic dispatch (ED) [2]. The power consumer and public utility can perform the optimizations of the demand response and economic dispatch, respectively. The optimizations of power consumption and supply can achieve the minimum costs under the assumption that the MDMS has complete information, which is provided by the smart grid data communications infrastructure.

The smart grid data communications infrastructure is a special purpose data network to support various smart grid applications. It is generally composed of the home area network (HAN) and neighborhood area network (NAN) connected with each other in a hierarchical structure to transfer the smart grid-related data. The reliability of the smart grid data communications infrastructure is important for the smart grid applications to operate optimally. Although a few work in the literature analyzed the reliability of such a network, they did not analyze the impact of reliability on the optimization of power consumption.

This letter illustrates the use of the smart grid data communications infrastructure to support power consumption optimization in the MDMS. Specifically, an optimization model is developed for demand response by deferrable load scheduling considering the reliability of HAN and NAN. These optimization models enable us to analyze the impact of the reliability of smart grid data communications infrastructure on the costs of the power consumption for the consumers. In particular, the deferrable load

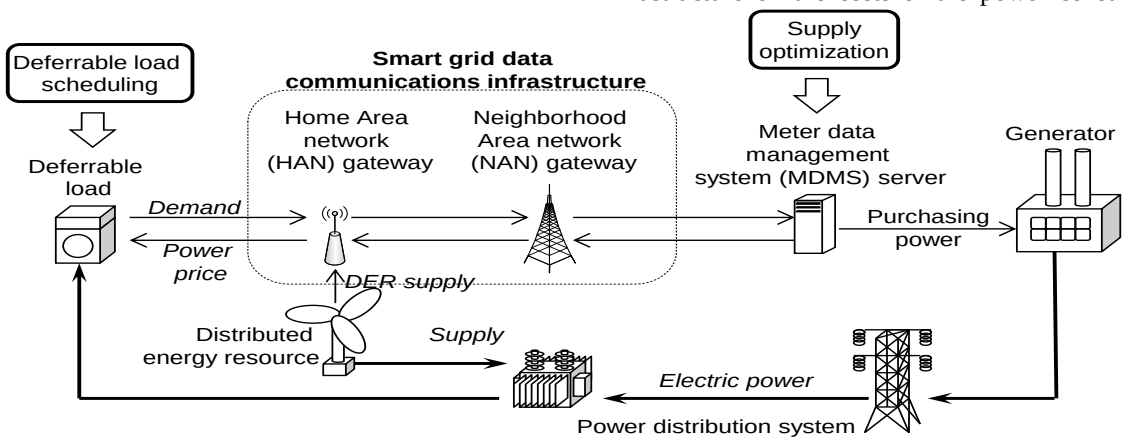

Fig. 1: System model of meter data management system (MDMS).

scheduling problem is formulated as a constrained Markov decision process (CMDP) model. The CMDP model considers connectivity (i.e., reliability of communications) between the deferrable load through HAN and NAN gateways and the MDMS server which determines the availability of the price information in making scheduling decision. The optimal scheduling policies are obtained under complete and incomplete information cases.

2. System Model

We consider the model of the meter data management system (MDMS) shown in Fig. 1 [3]. The MDMS belongs to a public utility. The public utility purchases electric power from generators and delivers it to the consumers or users through the power distribution system. The MDMS has a smart grid data communications infrastructure to facilitate power delivery among the public utility, consumers, and generators. The main components in the system model under consideration are as follows.

• Power Generator: The public utility purchases the electric power from the power generators. Different power generators can offer power supply with different prices and can have different capacities.

• Power Distribution System: The public utility operates a power distribution system which provides a facility (e.g., transmission lines and power distributions substations) to transfer electric power from the generators to the consumers.

• Distributed Energy Resource (DER): The DER is a small power generator (e.g., wind turbine or solar panel) to provide an alternative electricity supply to the users through the power distribution system. The DER can be installed by the users or the public utility.

• MDMS Server: The MDMS server is a centralized controller and provides data storage for the MDMS. In the system model under consideration, the MDMS server sends the power price information to the consumers and maintains the demand information from the consumers.

• Smart Grid Data Communications Infrastructure: The public utility uses a smart grid data communications infrastructure to inform the power price information to the consumers and also to collect the power demand from consumers and the power supply from DERs. Machine-to-machine (M2M) communications can be used for this purpose [4].

• Deferrable Load: The deferrable load is a special power consumption unit (e.g., dishwasher, washing machine, and computer) whose operation is divided into stages. The deferrable load does not need to operate continuously and it can be put in the wait state between two operating stages. A scheduling mechanism can be implemented such that the deferrable load can be operated with the minimum power consumption.

We consider that a service area of the public utility is divided into communities. Each community has a neighborhood area network (NAN) gateway (e.g., cellular base station) to provide two-way data communications between the MDMS server and home area network (HAN) gateways [5]. The HAN gateway provides a communication channel among power consumption units (e.g., through a smart meter) and DER in a local area (e.g., a house). On the uplink direction, the HAN gateway can collect the power demand information from the power consumption units, and power usage information from the smart meter. The power demand and supply information is reported to the MDMS server through the NAN gateway. In the downlink direction, the MDMS server sends the power price to the consumers (i.e., power consumption units), through the NAN gateway and subsequently the HAN gateway. The smart grid data communications infrastructure is part of an advanced metering infrastructure (AMI) [6].

We consider the reliability of the smart grid communications infrastructure. We can define a Markov chain to model the state (i.e., "available" and "repair") of the HAN and NAN gateways. The transition probability matrix of the Markov chain can be defined as follows:

$$\mathbf{C} = \begin{array}{c} \begin{bmatrix} 1 - 1/MTBF & 1/MTBF \\ 1/MTTR & 1 - 1/MTTR \end{bmatrix} \end{array} \begin{array}{l} \rightarrow \text{“available”} \\ \rightarrow \text{“repair”} \end{array}$$

where MTBF and MTTR represent the Mean Time Between Failure and Mean Time To Repair [7], respectively. The MTBF is a basic measure of the reliability of the components and systems. It represents the average time period between failures of a component and a system during operation. The MTTR is a measure of the maintainability of the repairable components and systems. It represents the average time period needed to repair a failed component or system. The first and second rows of matrix C correspond to the "available" and "repair" states, respectively.

In the consumption side, the deferrable load can be scheduled based on a different state (e.g., power price). This is also known as the deferrable load scheduling problem. For example, the deferrable load can run and consume power when the price is low, and defer the operation when the price is high. It is assumed that real-time pricing (RTP) [8] is used by the public utility for the demand side management (DSM). That is, the electrical price can be changed dynamically, which motivates the users to avoid consuming power during the peak period [2]. The deferrable load scheduler (i.e., a component, which runs the scheduling mechanism of a deferrable load) takes advantage of the price information transmitted through the smart grid

communications infrastructure to optimize the scheduling policy. This optimal scheduling policy can be obtained by formulating and solving a constrained Markov decision process (CMDP) model. However, if the price information is not available to the deferrable load, the optimal scheduling policy will be affected.

3. Constrained Markov Decision Process

We consider a deferrable load whose operation can be divided into $s_{\max}$ operating stages. The operation of each operating stage can be deferred for the maximum of $w_{\max}$ time periods [2]. The deferrable load may have a queue to keep the jobs from the consumer before running the jobs. The scheduler of the deferrable load can observe various states (e.g., power price information transmitted by the MDMS server through the NAN and HAN gateways) and make decision to run or to defer the deferrable load in different operating stages. The state space of the deferrable load is defined as follows:

$$\begin{aligned}\Theta \quad = \quad & \Big\{(\mathcal{S}, \mathcal{W}, \mathcal{P}, \mathcal{C}, \mathcal{Q}); \mathcal{S} = \{s_0, \ldots, s_{\max}\}, \\ & \mathcal{W} = \{w_0, \ldots, w_{\max}\}, \mathcal{P} = \{p_1, \ldots, p_{\max}\}, \\ & \mathcal{C} = \{\text{connected}, \text{disconnected}\}, \mathcal{Q} = \{0, \ldots, q_{\max}\}\Big\}\end{aligned}$$

where S is the operating stage of the deferrable load and $\{s_0,\ldots, s_{\max}\}$ is the set of all operating stages. W is the wait state (i.e., the number of time periods that the deferrable load has already deferred in the current operating stage). $\{w_0,\ldots,w_{\max}\}$ is the set of all wait states. P is the price state and $\{p_1,\ldots, p_{\max}\}$ is the set of all price states. C is the connection state (i.e., "connected" or "disconnected" with the MDMS server to obtain the price information). Q is the number of jobs in the deferrable load including the running job. $q_{\max}$ is the maximum number of jobs in the deferrable load. The general action space of the scheduler is Δ = {run, defer}.

The CMDP model can be expressed as follows:

$$\begin{aligned}\min_{\pi} \quad & \mathcal{J}_{\mathrm{C}}(\pi) \\ \text{s.t.} \quad & \mathcal{J}_{\mathrm{D}}(\pi) \leq D_{\max} \\ & \mathcal{J}_{\mathrm{F}}(\pi) \leq F_{\max}\end{aligned}$$

$\mathcal{J}_{\mathrm{C}}(\pi)$ is cost of the deferrable load, $\mathcal{J}_{\mathrm{D}}(\pi)$ is the average delay, and $\mathcal{J}_{\mathrm{F}}(\pi)$ is the probability that the queue is full. To solve the CMDP to obtain an optimal policy, we apply the linear programming approach.

4. Performance Evaluation

For deferrable load scheduling, we consider a deferrable load with 4 operating stages which can wait for 3 time periods. The length of a time period is 15 minutes. The deferrable load can have 4 jobs waiting in a queue. The job is generated with probability 0.1 in each time period. The probability threshold for the deferrable load to have maximum 4 jobs waiting in a queue is 0.01. The delay threshold of a job is 170 minutes. When the deferrable load operates, it consumes power of 1 kWh in all operating stages. On the other hand, when the deferrable load defers an operation, it consumes 10% of that in the run state. The probability of the deferrable load to finish running stage s in a time period is one. For the public utility, there are 3 price levels, i.e., 5, 10, and 15 cents per kWh. We consider the uniform price transition (i.e., probabilities of price 5, 10, and 15 cents per kWh are equal, i.e., about 0.333). The mean time between failure (MTBF) and the mean time to repair (MTTR) of a HAN gateway are 15,000 hours (i.e., 1 failure per two years) and 1 hours, respectively. The MTBF and MTTR of a NAN gateway are 8,780 hours (i.e., 1 failure per year) and 48 hours, respectively.

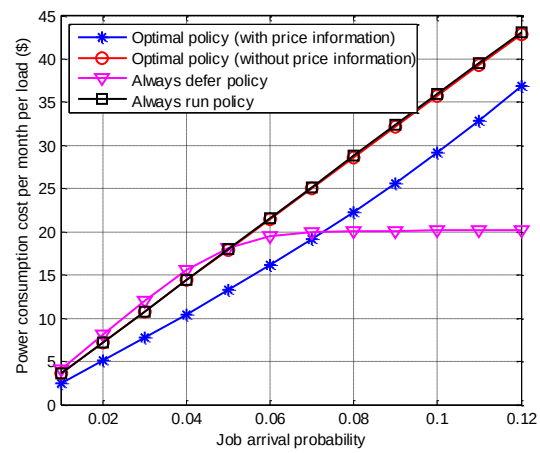

Fig. 2: Power consumption cost of a deferrable load.

We compare different scheduling policies for the deferrable load, i.e., "optimal", "always defer", and "always run". The optimal policies are obtained from the CMDP model, in which we consider two cases, with and without price information. In the "always run" policy, the scheduler always runs the deferrable load. In the "always defer" policy, the scheduler always defers the deferrable load, except when the last wait state is reached. Fig. 2 shows the power consumption cost of the deferrable load. When the job arrival probability is small (i.e., less than 0.07), clearly, the optimal policy with price information achieves the lowest power consumption cost, since the scheduler can defer running a deferrable load to the time periods when the price is known to be low. For a low job arrival probability, the "always run" policy achieves a lower power consumption cost than that of the "always defer" policy. The reason is that the load is deferred, it has to consume some energy during a wait state. By

contrast, if the load is run immediately, there is no energy consumption during a wait state. However, when the job arrival probability is large (i.e., more than 0.08), the "always defer" policy achieves the lowest cost, which is even lower than that of the optimal policy with price information. However, the "always defer" policy suffers from the long delay of a job (Fig. 3). Additionally, since the probability of full queue for the "always defer" policy is high, many jobs will not be accepted by the deferrable load, which mainly contributes towards the lowest power consumption. However, these behaviors of the "always defer" policy are undesirable from the user's perspective. The optimal policy with price information can maintain the delay of a job at the target level (i.e., 170 minutes). Although the "always run" policy achieves a small delay, the "always run" policy consumes more power than that of the optimal policy with price information. We observe that without price information, the optimal policy acts similar to that of the "always run" policy, whose power consumption cost is much higher than that of optimal policy with price information.

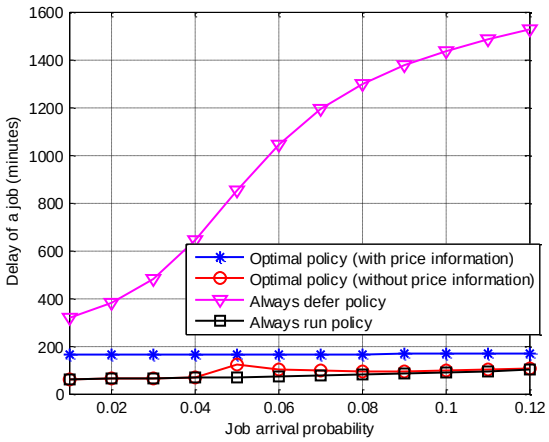

Fig. 3: Delay of a job.

5. Conclusion

We have analyzed the impact of reliability of the smart grid data communications infrastructure on the optimization of power consumption. For this, the deferrable load scheduling requires price information from the meter data management system (MDMS) server. If the connection of home area network (HAN) and neighborhood area network (NAN) gateways from deferrable load to the MDMS server is unavailable, the scheduling policy will be suboptimal and it will result in a higher power consumption cost. A similar methodology can be used to study the impact of reliability of the smart grid data communications infrastructure on the optimization of power supply [1] and demand side management [9] in the smart grid environment. In the above contexts, some potential future research directions are as follows. The network deployment can be optimized to determine the sufficient number as well as the locations of the gateways to achieve the desired level of communication reliability. Machine-to-machine (M2M) communications infrastructure as defined in the 3GPP LTE-A (and beyond) systems can be customized/optimized to support MDMS data exchange. Also, the idea of local MDMS data dissemination, e.g., power price, can be explored to provide communication redundancy.

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Electric Vehicles and Fast Charging Stations: A Feasibility Study

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1. Introduction

As concerns on the environmental pollution and lifetime of carbon fuels are growing, increased interest is focused on the introduction of vehicles powered by alternative fuel, such as hydrogen or electricity. This lead in the last years to an increased popularity of electric vehicles (EV). EVs can be purely electrical or hybrid, as the charging time is currently relatively long as compared to refueling with gasoline, even when fast charging is employed. Figure 1 provides an overview of the charging time depending on the input voltage for some EV models.

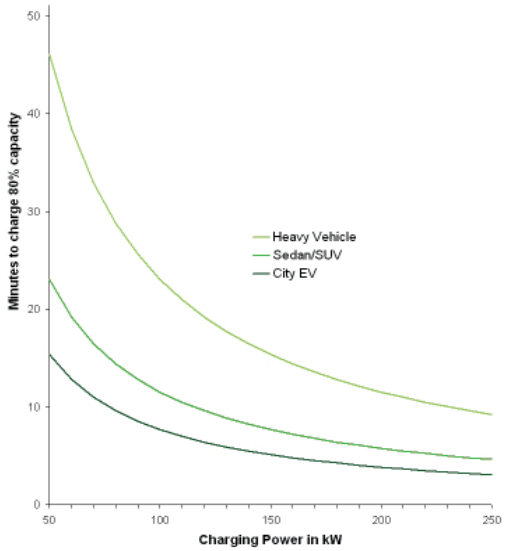

Figure 1. Charging time for different EVs.

In this scenario, Plug-in Hybrid Electric Vehicles (PHEV) are becoming gradually more attractive than internal combustion engine or purely electrical vehicles, as they aim at merging the advantages of both designs. Nevertheless, to fully exploit the electric engine, fast charging stations are required, mainly for two reasons: (1) night charging at the customers' home takes longer time and the current electrical grid is not potentially able to support the required power demand increase (see Figure 2), and (2) electrical engines have usually limited range (around 100 km).

Fast charging stations are characterized by high charging voltage, in such a way to minimize the charging time, and should be located in strategic locations for easy and convenient access.

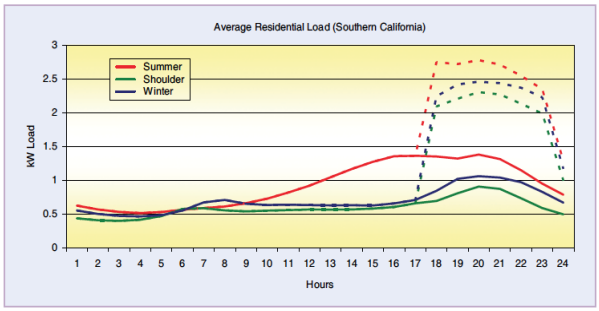

Figure 2. Average residential load in Southern California. Dashed curves represent the increased load due to EV charging at home.

Acknowledging that design and development of fast charging stations has crucial importance, this paper overviews an analytical model for a PHEV charging station architecture, that allows to analyze the performance of the system by using arguments from queuing theory and economics.

To the goal of designing a general architecture which will be able to sustain grid stability, while providing a required level of quality of service, the considered charging station model includes an energy storage component to store excess power obtained from the grid. The proposed methodology allows to analyze the performance of fast charging stations with respect to the traffic characteristics, energy storage size, pricing and cost parameters.

Other works are available on fast charging stations [3-6], but they are focused on a centralized scheduling architecture and are mostly targeted to optimize the distribution of the beginning and completion of charging more than on the design of the charging stations.

The following sections provide a description of the fast charging station model used for the analysis (Section 2) and its extension to the case of multiple charging stations (Section 3). Finally, Section 4 concludes the paper.

The reader interested in this work can find additional and extended technical details, that could not be accommodated in this short letter, in [1] and [2].

2. The proposed fast charging station model

In this section, we introduce a model of the fast charging station for PHEVs. This basic model includes a constant power supply from the grid as well as a local

energy storage facility to save un-utilized excess power (see Fig. 3).

Clearly, the power demand to the fast charging station fluctuates over time, as it depends from the vehicles arrivals (assumed to happen with a Poisson distribution with average λ_j arrivals per hour). Priority is given to the usage of the power supplied by the grid, with the energy storage being used in addition to cope with increased demand.

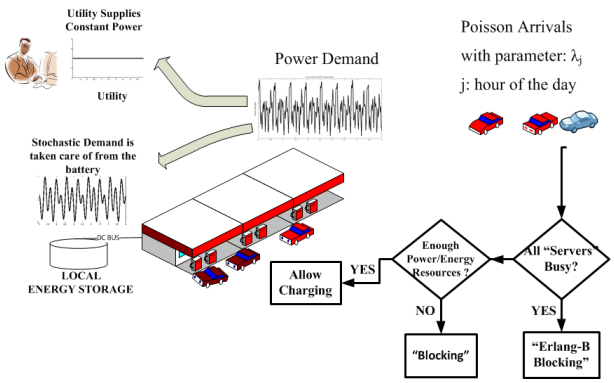

Figure 3. The proposed EV fast charging station model.

Overall, if S represents the number of vehicles that can be charged by the grid and R is the capacity of the local energy storage, the maximum number of customers that can be served is equal to S+R.

In order to study the behavior of this system, it is possible to define a queueing system whose elements are the PHEVs and whose state is the number of PHEVs being served at a given time (blocked customers are rejected by the system). The resulting model is a Markov Chain, which can be studied for steady state behavior (more details are provided in reference [1]).

The queueing model allows us to derive indications about the dependence of the performance in terms of the other design parameters. As an example, Fig. 4 plots the cumulative gain in terms of blocking probability increasing the energy storage size, and shows that as the capacity of the local storage approaches the charging capacity provided by the grid the resulting gain is quite limited – while the presence of local storage is extremely effective by itself.

Figure 5 depicts the supported arrival rate (in vehicles per hour) with a controlled upper bound on blocking probability (the parameter Pb) versus the maximum charging capacity of the system. Depending on the tolerance on Pb, the system may support higher flows of vehicles.

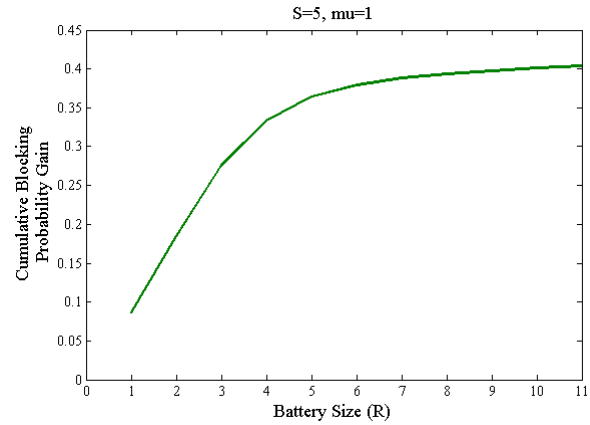

Figure 4. Average gain in blocking probability vs. battery size.

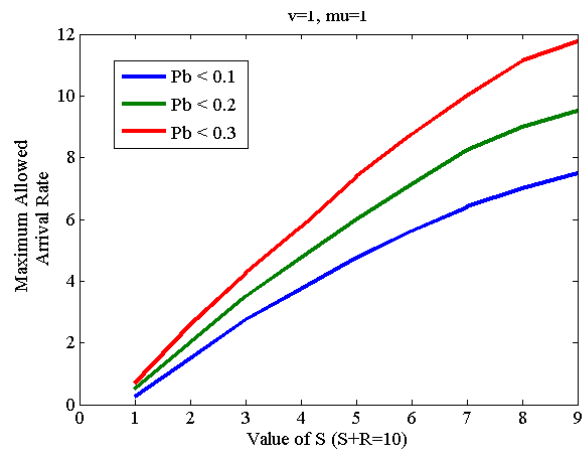

Figure 5. Supported arrival rate vs maximum number of vehicles that can be served.

Based on the solution of the Markov Chain modeling the fast charging station, it is then possible to define a suitable function for the net profit for the owner of the fast charging station (see [2]), and to derive the optimal arrival rate to maximize such profit. The result looks similar to what is plot in Fig. 6.

3. Further steps forward: multiple charging stations

After analyzing the single fast charging station system, it is then possible to extend the model to a network of fast charging station, as presented in [2].

From what was found for a single charging station, ideally each charging station should aim to achieve the optimal arrival rate which maximizes the net profit. Therefore, the best scenario involves the usage of communications among the fast charging stations and between charging stations and customers in order to reach such optimal configuration. Such result will maximize the net profit and minimize the overall customer blocking probability, at the price of supporting rerouting of customers.

4. Conclusions

The letter provides an overview on the usage of fast charging stations for PHEVs. The usage of a compact model based on queueing theory enables to identify the relationships among the station's design parameters and to study how profit by the station owner and benefit for the customers can be maximized.

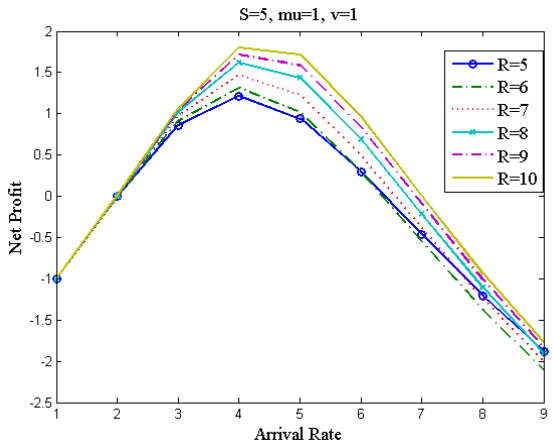

Figure 6. Net profit vs vehicles' arrival rate.

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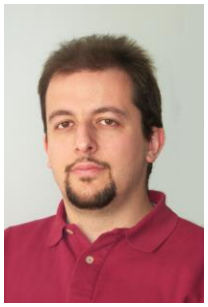

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A Wi-Fi-based Power Metering System for Energy Management and Controlling

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1. Introduction

Continuity of developments in technology obligates the energy planning and management as a concomitant of the existing resources' inadequacy in satisfying increasing needs. To meet the rising demand of energy, research efforts are densely focused on the applicable ways of both the increment in energy consumption efficiency and the effective use of existing power sources. Considering approximately %40 of the total produced energy, worldwide, is consumed in home derived residential places and commercial buildings, the dwellings should be targeted correspondingly to resolve the ongoing problems on energy sustainability. In this regard, Energy Management Systems (EMS) come into prominence to consume the energy more effectively by consumption scheduling, usage regulation and standby power reduction operations [1-9]. Since these systems serve beneficial solutions in terms of energy utilization, there is still room for enhancements.

The main constraints of energy management strategies include how and when to wake up and turn back to normal operation from the standby deactivation, and how to recognize a plugged device and its specifications to fulfill the targeted efficiency while enabling mobility, adaptivity and flexibility.

There exist several preceding solutions developed for these problems [1], [4], [8]. For changing the operation from standby to normal mode, a remote controller-based system was proposed; however, requiring two times control and extra hardware utilization made this effort inconvenient. Alternatively, a simple timer may be used for this issue, but the synchronization becomes crucial what inevitably compels the proper system operation. In addition, IR technology was used for waking up the devices; however, being applicable for only the appliances which are operated by a remote controller was resulted in inadequacy. For the recognition of connected devices, behavior estimation-based efforts were proposed by using sensory structures or duty commands directed by user's itself; however, these methods require additional costs and precise estimation of unknowingly upcoming events. On the other hand, the proposals built by button and/or magnet derived components restrict the flexibility of controllable device diversity.

In this paper, we present a new Wi-Fi-based power metering system, i.e., smart plug (WSP), for both demand side energy management and real-time control and surveillance of middle class household appliances. This proposed structure is essentially based on a standby power cut off algorithm built with more precise calculation of consumed power, and an UI development to be used for decreasing the existing device recognition, mobility, re-energizing and chain delay drawbacks of previously proposed EMS. With the experiments realized in real testbeds by using real devices, energy and cost effective structure of WSP has been proved.

2. System Details

In this section the basic architecture and the developed system model of the proposed smart power meter, WSP, is discussed, respectively.

WSP Architecture

Fig. 1 represents the basic structure and the interactions of this new Wi-Fi-based gateway that formed by 6 main units, namely power metering, energizing, switching, management, communication and monitoring. As considering the plug is serially connected between the hot line and the device as a bridge equipment, the terms related to energy; type, amount and flow, need to be precisely regulated to sustain the proper system operation. When taking into account the AC voltage existing in hot line has to be correspondingly converted into DC to energize the system parts by adjustable outputs, an AC/DC converter with some additive components is implemented.

To enhance the reliability of switching operations, we tried to construct a collaboratively working unit by using not only a relay but also additional sub-components and supportive circuitries. A PCB type 220V-10A single phase dry contact relay is combined with an opto-isolator to enhance the isolation and decrease the negative effects of both harmonics and high breaking currents by switching the circuit at zero crossings. The relay requires only 5V transient tripping impulse directed from MCU to switch the plugged devices. In addition, a filter placed before the energy input to regulate the voltage rippling and eliminate the thermal noises.

Previously proposed efforts handled the power measurement by using voltage dividers and current sensor derived simple circuitries; however, the unit assigned for this task should also be able to measure the power factor (PF) in addition to current and voltage

values for more accurate calculation of real power consumed. To actualize that Cirrus Logic's low priced energy measurement analog front-end (AFE), namely CS5490 is performed. The AFE is equipped with an EXL signal processing core to measure and calculate the active, reactive, apparent and instantaneous power levels, RMS values of voltage and current, power factor and line frequency.

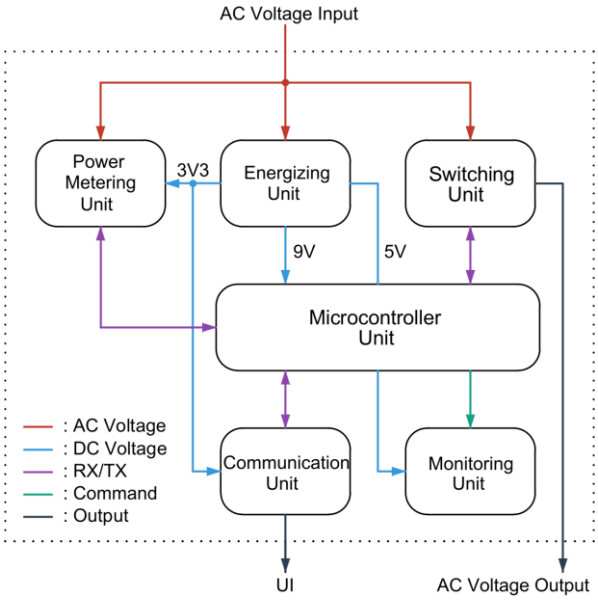

Figure 1. Connection and flow diagram of WSP.

For the flexible management of the system, a compact constructed, low cost and low power consumptive microcontroller, namely Atmega328, is preferred. It consistently interacts with all the remaining units to perform the predefined control, measurement and managing duties, and transfer the evaluated data to the UI over a communication protocol. Although there exist several technologies classified as wired and wireless to compose the network and convey the data, an IEEE 802.11.n, i.e., Wi-Fi, standard-based 2.4 GHz ISM band operative wireless communication module, namely ESP8266, is preferred in this work as a result of having good coverage capabilities, providing high data rates and being compatible with laptops and/or smartphones, thus not requiring any additional hubs to be used as a relay equipment between the devices and the user which alters the system's cost effectiveness by serving advanced network connectivity. All the data related to power consumption and/or system status gathered from the device which is plugged over AC voltage outlet are simultaneously sent to both monitor and UI for real-time energy awareness and/or decision making procedures.

Main Enhancements.

As it is mentioned, existing EMS have some drawbacks on the topics of mode changing, device recognition, mobility, and system delays which are needed to be enhanced for more efficient automation strategies. There are two known proposals developed for the device recognition issue [1], [8] which can be directly linked to increase the effectiveness of standby power consumption. The first one was constructed with buttons to specify the targeted device for flexible arrangement of the operation area/mode and the management of the power usage. Second one includes magnet utilization to set up a magnetic field and generating particular binary codes to recognize the connected device, correspondingly. Although these systems provide simple solutions for precise estimation of the plugged devices' characteristics and preventing the energy wasting, there is no need to equip both EMS and end-devices with redundant extra hardware. Because, the targeted device is already known due to connecting by user's itself, so that it is unnecessary to deal with identification, since devices are addressed to the UI over the related power meter. Instead of using magnet and/or button derived additional components, conventional power metering techniques have been enhanced for more precise measurement of real consumed power by using high accurate energy metering ICs and advanced software. That attempt results in easily and reliable recognition of domestic products thanks to more precise consumption precision that increases the mobility and extends the application range. This enhancement also helps to eliminate the restrictions on the operable device density considering the limited number of magnetic labels and buttons to be placed/deployed, thus almost all the household appliances become manageable over WSP without any exceptions.

The second major concern is focused on how to wake up the switched off devices and turn back them to their normal operation. Instead of using additional remote controllers, IR buttons and/or behavior estimation capable sensors [2], [3], [6], [7], all the plugged devices are organized in the order of star topology and managed by a mobile application, which acts like a UI, over an android-based smartphone. That resolves the unnecessarily utilization of additional hubs, end-devices and/or gateways to be connected to near-user monitors, which correspondingly reduces the communication delays by preventing redundant hops to convey data to their destination. It also increases the system convenience by eliminating the possible malfunctions owing to faults in behavior prediction. That user friendly and reconfigurable android-based UI provides versatile mobile functionality, allows remote, programmable and automatic control of devices, and increases the human interaction with the system for the real-time management of the operation mode. Star topology, enabled by Wi-Fi technology, leads to point-

to-point communication that disaggregates the network components and resolves the misunderstanding of individual energy consumption of each appliance. With this enhanced awareness of demand side energy usage, it becomes possible to shift the residents' behaviors to mitigating energy consumptions in dwellings. This and the mentioned standby power reduction method are targeted to enhance the power consumption efficiency.

3. Performance Evaluation

Home appliances can be classified as controllable and uncontrollable depending on the tasks they performed. It is not possible to de-energize an uncontrollable device, such as a refrigerator and/or a telephone, because these appliances have to be turned on perpetually. Regarding that, 10 different controllable household devices were connected one by one to WSP for the measurement of standby power usage to test the system performance. Their consumptions was calculated by sampling the measured value at every 50 milliseconds and averaged over 20 samplings, then the corresponding results stated in Table 1. As shown from this table, the most power consumptive device appears to be the set-top box which consumes approximately 11.38 watts while it is not under operation.

WSP periodically monitors the power consumption of the plugged device to cut off the AC power as soon as the measured value falls below the threshold for a predetermined time. Therefore, it is set to cut off the standby power with an urgent command directed from MCU to relay unit when the measured power value holds below 12 watts for one minute.

No.	Appliances	Avg. Standby Power (W)
1	TV	3.4
2	Set-top Box	11.38
3	Personal Computer	2.87
4	Monitor	2.41
5	Printer	2.92
6	Modem (DSL)	5.38
7	Washing Machine	1.86
8	Microwave Owen	2.56
9	Dish Washer	2.27
10	Air Conditioner	5.3
Total		40.35

Table 1. Measured average standby power consumption values of controllable middle class household appliances.

WSP consumes relatively low power which varies from 342 to 784 mW depending on the operation mode, thanks to developed algorithms, equipped advanced components and collaboratively working circuitries, what makes the total consumption negligible as regarding the consumed power by the connected devices.

Considering total redundant use of the targeted appliances fluctuates at the level of 40.35 watts, and the average operation time in standby mode is assumed as 10 hours per day, it is possible to save approximately 350 Wh in daily, and correspondingly 10 kWh energy in monthly basis.

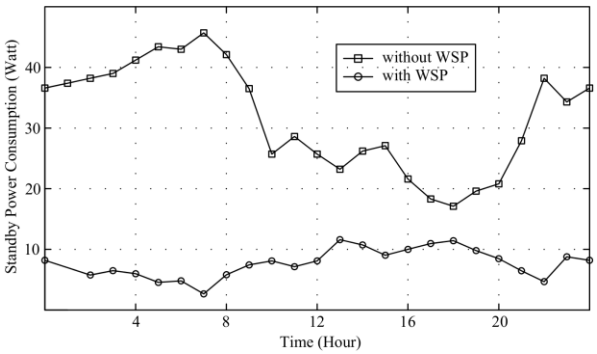

Figure 2. Comparison of standby power consumptions

As seen in Fig. 2, standby power consumptions are roughly vanished, and the right, cheap and more effective use of energy becomes possible with the utilization of WSP.

Real time consumption monitoring is proposed not only for energy awareness but also for system and device security by detecting abnormal and/or improper use of electricity to prevent the potential unfortunate consequences. In addition to that, to protect the sensitive devices from the possible negative effects of the instant voltage fluctuations induced by the grid, a security algorithm is built with this model for cutting off the power in urgent situations. These attempts help to create a more secure environment for both appliances and the users.

In addition to what is mentioned above, this system can be denoted as more applicable and cost effective by bypassing extra hardware and software necessity; more flexible, mobile and adaptive thanks to the conducted algorithms, and more accurate in energy monitoring by advanced power metering techniques, and user friendly and reconfigurable UI support.

4. Conclusion

In this work, a new power metering gateway based on Wi-Fi technology has been developed for not only demand side energy management but also advanced real time control, monitoring and management of home appliances. This proposed structure is mainly focused on the problems of device recognition, mobility, re-energizing and chain delays of previously proposed EMS. As a result, a more secure, accessible, mobile, controllable and versatile system has been achieved.

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Electric and Autonomous Vehicles in the Smart City: Impact on Energy, Transport and Communication Infrastructures

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I. Introduction

Two important trends characterize the current vehicle evolution electric propulsion and autonomous driving. Replacing combustion with electric engines is necessary for sustainability as well as for air pollution mitigation. The introduction of the autonomous vehicle is motivated by road safety (most accidents are caused by human error), by energy and pollution benefits (the autonomous vehicles smoother drive enhances both) and, most important, by drivers convenience and stress reduction. These two trends are interrelated, mainly because most autonomous vehicles are electric due to the fact that the electric engine is easier to control robotically than the combustion engine. Both trends pose challenges to the city most critical Infrastructures, namely, Energy, Vehicular Transport and Mobile Communications Infrastructure In this paper we address three such challenges: (1) the battery recharging problem and its impact on the energy grid; (2) the EV traffic management problem, now subject to more constraints than before, with combustion engines, and; (3) the CACC (Cooperative Advanced Cruise Control) communications requirements and their impact on the Vehicular Communications Network.

II. Battery recharging and impact on the Grid

Battery recharging is the most delicate and controversial aspect of an EV (Electric Vehicle) strategy. Given battery charging stations with options of quick/slow charging and swapping and power pricing with temporal and spatial variations, the Vehicle Navigators jointly with City Traffic Planners must decide when, where, and how to replenish batteries, which routes to use to recharge most efficiently, how much energy to allocate per charging station. If swapping is used, how many batteries must be allocated per vehicle and per swapping station. Furthermore, charge station planning (placement and options), battery replenishment strategy and route selection must be formulated and solved simultaneously as joint problems.

Battery replenishing will stress the power grid in different ways depending on the time and level of the energy it draws [1]. But it may make the power grid more robust if batteries are used wisely as energy storage for the power grid. To this end, the following mechanisms must be considered by planners: (i) batteries in plug-in EVs, (ii) batteries at battery swapping stations, and (iii) second-life batteries; that is, batteries retired from EVs when their energy capacity degrades due to aging. For rechargeable batteries, some recent studies have shown that the first 30 percent of cycles of Li batteries may be used in EVs, but the remaining cycles are better suited to energy storage in the power grid. For plug-in EV batteries, if the prevalent source of renewable energy is solar, it will behoove to charge batteries during the day using abundant solar energy

Fig. 1. Map of Los Angeles

and resell this energy in the evening hours. This would place a burden on office buildings and Industrial/Academic Campuses where people park their vehicles during the day. Moreover, commuters should plan to arrive at work on empty. This underlines the interconnection between EV storage, Grid energy distribution and transport strategies discussed in the next section.

III. Vehicle routing and traffic management problem

Consider the Planner of a large fleet of Electric Vehicles in the Greater Los Angeles area. The Planner must optimize the flows of EVs in this maze subject to congestion, pollution, energy storage and battery recharging constraints. From published passenger and freight traffic statistics the Planner computes the traffic matrix. Pollution sensitive pathways are identified and time dependent penalties are assigned to various non-electric vehicle classes. This simple traffic study will allow to derive key performance measures such as differential end to end delays, operating costs for EV and conventional vehicles, and; refuel/recharge station costs. These figures will also give a good indication of the potential growth of the Electric Car. In fact, electric vehicles will travel on more direct routes, traversing dense residential areas (since they have no pollution restrictions) and using preferential lanes.

The quasi-stationary solution obtained with the theoretical formulation is adequate for a multitude of trade off studies and does provide the answers needed by most stakeholders, from auto makers to policy makers, city planners, utility operators and consumers. The model allows for a high level strategy evaluation and comparison as well as fine tuning of the game actions.

One must also show that the optimal solution generated by the flow and game optimizer is realistic. In the past, the main challenges were: no precise knowledge of traffic demands; inability to enforce routing decisions and; inability to track traffic as they evolve. Fortunately, now on board navigators

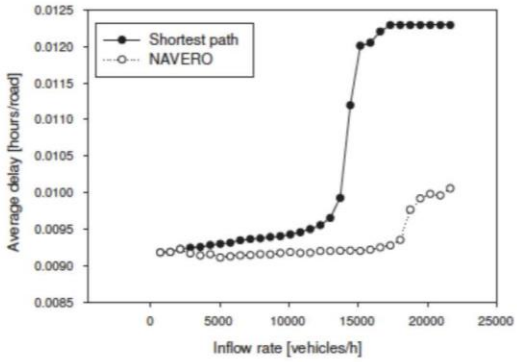


Fig. 2. Planner Analytic Results

are equipped with GPS and two-way communications with the Navigator Server or Fleet Planner. The vehicles continuously report time, position and target destination to the Fleet Planner. By monitoring these messages, the Fleet Planner acquires the traffic load and learns the traffic sources and destinations. It can thus optimize the flows and routes and can instruct vehicles to follow those optimized routes. The optimization includes the energy and pollution costs set by the City Planner. The Fleet Operators may then discourage their vehicles from entering the urban grid when operating costs are prohibitive, advising them to wait at the boundary. This input traffic regulation and scheduling will be implemented differently for passenger vehicles and commercial fleets.

For passenger vehicles, a common critique to centralized route management is that with current on board navigators the driver does not need the Navigator Server (or Fleet Planner) for routing instructions. Following the global traffic load map, the on board navigator directs the car to the least delay route. Unfortunately, the on board optimization cannot account for the unpredictable delays in the feedback control loop (from several minutes to hours!). Thus, in heavy traffic the local navigator causes route flapping. Moreover, the local navigator may not know the latest pollution and energy costs; and, it cannot exercise fair input regulation and control.

To validate the Planner analytic results, the SUMO urban simulation model has been used. Preliminary results with the tool NAVERO (Navigator Assisted Vehicular Routing) built on SUMO are reported in Fig. 2 [2].

The results show consistency between the centralized optimization model and the distributed on Board Navigator implementation. As the vehicle inflow rate increases, the shortest path solution suffers very high delays. Both optimal solution (not shown) and NAVERO solution use multiple paths in parallel to reduce delay and congestion.

Besides providing a validation of the centralized solution, the simulator allows the designer to study the evolution of traffic (and of associated performance) as a function of Energy and Pollution Agent decisions, which in turn depend on traffic and routes.

IV. EVs and Autonomous Vehicles New Communications Requirements

There is an interesting trend in the Automotive market today: vehicles are becoming independent not only of fuel but also of drivers! Namely, Autonomous Vehicles (mainly electric, of course) are becoming driverless. The transition has been incremental, with the introduction first of ACC (Advanced Cruise Control) relying only on radars, and then of CACC (Cooperative ACC), where cars can talk to each other via Radio (DSRC, LTE, WiFi etc). Both ACC and CACC are making the task of driving easier. CACC however requires V2V communications, with new impact on the Wireless Communications Grid. In this section we examine the first most important manifestation of Autonomous vehicles on the highway Platooning. We elaborate on the safety and stability of Platoons and discuss the special communications requirements of this operation.

A. Platooning

Platooning can enhance the travel experience covering consumption issues, safety, and comfort. First, it has the potential to improve the traffic flow and to reduce the fuel consumption, reducing jams on freeways and decreasing pollution [3], [4]. Second, platooning can improve drivers safety if a system fault is less likely than a human error, which is the main cause of accidents [4]. Last but not least, a vehicle autonomously following its leaders permits the driver to relax, as shown by the recent SARTRE project [5].

From a research point of view, platooning is extremely challenging, as it involves several research fields including control theory, communications, vehicle dynamics, and traffic engineering. For what concerns networking, any controller designed for supporting platooning, such as Cooperative Adaptive Cruise Control (CACC) in [6], [7], needs frequent and timely information about vehicles in the platoon to avoid instabilities that might lead to vehicle collisions. A platooning system has a recommended information update frequency of 10 Hz [7]. Whether these communications requirements can be satisfied by the plain DSRC/WAVE stack [8] is still unclear, and further work is needed before platooning can become a reality.

B. Part A Why do we need CACC?

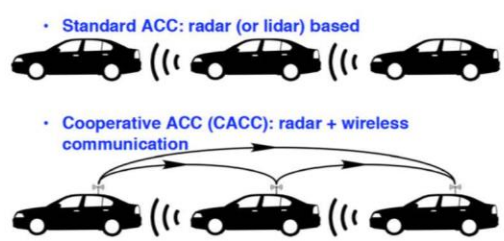


Fig. 3. Platoon Control Systems

As earlier discussed, highway lane occupancy can be increased by reducing the inter-vehicle distance. The amplification of velocity disturbances in the upstream direction, however, poses limitations to the minimum feasible spacing policy. Stable behavior is thus an essential requirement for platooning. Theoretical analysis and experimental studies reveal that stability requires V2V communications to provide

each car with real-time information of the platoon lead as well as of the preceding vehicle. The latter can in part be obtained from Lidar or Radar signals supplied by conventional Adaptive Cruise Control (ACC). Fig 3 shows the difference between ACC and CACC. A simulation study performed on a six passenger vehicle platoon clearly demonstrates the importance of CACC (and thus V2V) platoon stability.

Fig 4 reports the results of an experiment where the lead car moves erratically varying its speed by 10 kph in 5s. The top left figure shows the velocity of the cars in the platoon when headway between cars is T = 0.3s. The velocity of the last car is totally out of Phase suggesting that a crash may be imminent! Increasing the headway time (to T = 1.2 s) as shown in the top right plot, smoothens out the oscillations and stabilizes the system, but it increases the gap from 10m to 30m, neutralizing the benefits of platooning! Surprisingly, CACC can maintain perfect stability with just 5m gap that is independent of speed. These results show that without CACC there is no platooning.

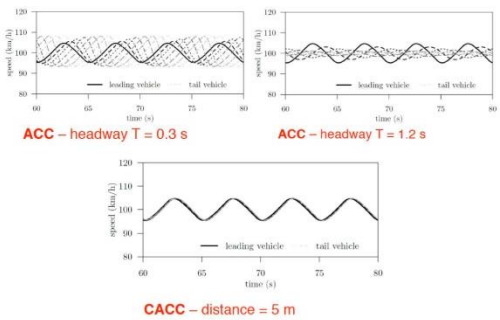


Fig. 4. Controller Comparison

C. Part B Is CACC feasible with todays safety beacons?

To study the suitability of state of the art beaconing protocols for platooning and to highlight the challenges that are still open, our Lab in Trento IT has investigated the channel load imposed by a large number of platoons on the road. The results reported here show the comparison of various beaconing schemes, namely:

- **Dynamic Beaconing (DynB):** DynB maintains channel load at the desired value of 25
- **Transmit Rate Control (TRC):** TRC carefully adapts the beaconing rate to prevent channel congestion
- **Slotted beaconing protocol (SLB):** with adaptive power control
- **Slotted beaconing protocol with fixed Power (SLBP):** fixed power P
- **Static beaconing protocol (STB):** with adaptive power control
- **Static beaconing protocol with fixed Power (STBP):** fixed power P

The rationale behind the slotted beacon protocols is to reduce random channel contention by adding synchronization among nodes. To determine power control in SLB, we can exploit the fact that, besides the leader, each vehicle needs to communicate its speed and acceleration only to the vehicle immediately behind. The transmit power can thus be reduced in order to increase spatial reuse and avoid interfering with cars that are not interested in receiving such data. Leaders must still use high transmit power in order to reach all vehicles within the platoon. To determine Time Slotting, we exploit vehicles position within the platoon. The leader can send its beacon first, then the others can follow in a cascading fashion, i.e., the second vehicle, the third, and so on. Notice that this is different from a standard TDMA approach, as with TDMA every node participating in the communication obeys the same rules. In this case, only nodes within a platoon cooperate in a TDMA-fashion in order to reduce intra-platoon channel contention.

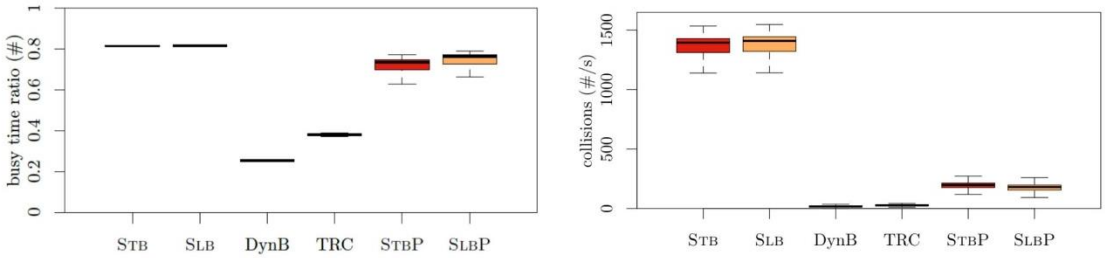
The fixed beacon interval value of 10 Hz and transmit power control capabilities only holds for STB and SLB. DynB and TRC compute their own beacon intervals, and always use 20 dBm as transmission power.

We simulate a stretch of a 4-lane highway filled by platoons of 20 cars each, for a total number of cars of 160, 320, and 640, respectively.

1) General Networking Performance: First, we analyze the network behavior, varying the total number of cars and thus channel load. The goal is to understand behavior of the protocols based on typical network metrics: channel busy ratio and collisions. The channel busy ratio is measured at the physical layer and averaged every second: each node samples how much time the channel was declared busy by the network interface card. Collisions are estimated as the number of not correctly decoded frames (per second and car) due to interference. Fig **??** shows collision statistics for the 640 cars scenario (the most demanding in terms of network resources) using boxplots, thus displaying the first and third quartiles as a box and the median as center line, as well as the minimum and maximum value with whiskers.

The first evident difference between the proposed approaches and the dynamic protocols is in the channel busy ratio. DynB maintains channel load at the desired value of 25%, independent of the number of vehicles, while TRC has a higher channel usage but still way lower than STB and SLB. STB and SLB completely saturate the channel as they do not employ transmit power control and hence cause a huge amount of collisions as can be witnessed in Fig **??**. In comparison, STBP and SLBP are able to avoid complete channel saturation and drastically reduce the number of collisions in the channel, suggesting that transmit power control can give a huge benefit. Notice anyhow that the usage of the slotted approach results in a better utilization, as shown by the increased channel busy ratio and the lower collisions. Yet, DynB and TRC definitely show better performance with respect to the considered metrics.

From the above study we conclude that a combination of transmit power control plus slotted scheduling can support frequent updates to the CACC controller without incurring high packet losses. Power control keeps network utilization in check when the number of vehicles increases. At the same time, SLB reduces the number of collisions by avoiding random channel contention



(a) Busy time ratio **(b)** Collisions per second

Fig. 5. The busy time ratio averaged every second and collisions per second for the 640 cars experiments.

V. Conclusion

The emerging Electric Vehicle with self driving capabilities will pose new challenges to the Energy Grid, with demands that must be satisfied with tight time and space constraints (as opposed to much more relaxed fossil fuel provisioning constraints). This in turns will place constraints on urban Transport, eg, planning of EV routes that must include recharge stations. The need to drive autonomous EVs in platoons to save energy and improve road occupancy will require V2V communications between car and from car to infrastructure. In rush hour these time sensitive V2V requirements between cars will pose a challenge to the already overloaded WiFI spectrum. In summary, the vehicle will be at the center of three critical infrastructures, Energy, Transport and Communications.

Dr. Mario Gerla is a Professor in the Computer Science Dept at UCLA. At UCLA, as a Graduate Resarcher in 1969 he was part of the team that developed the early ARPANET protocols under the guidance of Prof. Leonard Kleinrock. He joined the UCLA Faculty in 1976. His research involves mobile communications and applications. His team is developing a Vehicular Testbed for safe navigation, content distribution, urban sensing and intelligent transport.

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To ensure appropriate consideration of conflicts of interest during the review process, the ComSoc prohibits changes to the list of authors once a paper has been submitted for review during review, revision, or (if accepted) final publication. The author list may be changed only prior to the submission deadline. Additional paper submission instructions, including the double-blind policy, can be found on the conference web site www.ieee-infocom.org/2016. To be published in the IEEE INFOCOM 2016 conference proceedings and submitted to IEEE Xplore®, an author of an accepted paper is required to register for the conference at the full (member or non-member) rate and the paper must be presented by an author of that paper at the conference unless the TPC co-chairs grant permission for a substitute presenter before the conference. Non-refundable registration fees must be paid prior to uploading the final IEEE formatted, publication-ready version of the paper. For authors with multiple accepted papers, one full registration is valid for up to 2 papers. Accepted and presented papers will be published in the IEEE INFOCOM 2016 conference proceedings and submitted to IEEE Xplore®.

Submission Instructions

Only original papers that have not been published or submitted for publication elsewhere will be considered. Technical papers must be submitted via the EDAS Paper Processing System. Submitted papers should be written in the English language, with a maximum length limit of 9 printed pages, including all the figures, references, and appendices. All submitted papers will be judged based on their quality and relevance through double-blind reviewing, where the identities of the authors are withheld from the reviewers. Authors are required to make sure that the complete list of authors are provided as part of the metadata to EDAS, however, the list of authors should not be included in the paper PDF document in accordance to the double-blind submission policy. Please refer to the following website for detailed submission policies and instructions: http://infocom2016.ieee-infocom.org/authors/paper-submission.

Call for Papers

IEEE Conference on Standards for Communications and Networking (CSCN 2015)

Tokyo, Japan, 28-30 October 2015

http://www.ieee-cscn.org

Standards play a key role in the success of the communications industry, as enablers of global systems inter-operability. IEEE CSCN aims for closing the gap between researchers, scientists and standards experts from academia, industry and different standardization bodies. It will serve as a platform for discussing standards-related topics in the areas of communications, networking & related disciplines, facilitating standards development and cooperation among key players.

IEEE CSCN is inviting submission of high quality technical as well as visionary papers, which will be reviewed and selected by an international Technical Program Committee (TPC) representing both academia and industry, with a strong standardization background. Topics of interest include, but are not limited to, enhancements to existing systems and communication protocols developed by standards bodies such as ITU-T, IEEE, IETF, 3GPP, ETSI, OMA, GSMA, Broadband Forum, Metro Ethernet Forum, oneM2M, ONF, among others. Visionary papers on hot topics, such as Advanced 5G Radio Access and Network Infrastructure, Converged Access Networks, Optical Networks, Twisted Pair and Coaxial Access Networks, Software Defined Networks and Services, Network Functions Virtualization (NFV), and other works in progress being currently discussed by the standardization bodies will be included.

The conference will also solicit papers on the relationship between innovation and standardization, technology governance of standards, the history of standardization, tools and services related to any or all aspects of the standardization lifecycle, and compatibility and interoperability, including testing methodologies and certification to standards.

Accepted and presented papers will be published in the IEEE CSCN Conference Proceedings and submitted to IEEE Xplore® as well as other Abstracting and Indexing (A&I) databases. The conference's best papers will be recommended for publication at the IEEE Communications Magazine's supplement on Communications Standards.

IEEE CSCN will also include several panel sessions and keynotes focusing on the broad issue impacting standards directions in the telecommunications sector. Tutorials on topics of critical interest across multiple SDOs will be also considered.

IEEE CSCN will accommodate the following special industry sessions, allowing companies to explain their latest offering that embodies some specific new standards:

- Advances in Vehicular Communications
- Software Defined Sensors Networks and IoT: perspective and proposals for new standardization activities
- Optical Wireless Communication

IEEE CSCN 2015 will take place in Tokyo immediately preceding and located adjacent to IETF's 94th Plenary in Yokohama, Japan.

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JaeSeung Song, Sejong University, Korea
Tuncer Baykas, Istanbul Medipol University, Turkey

Important Dates

Paper Submissions: **July 1, 2015** Notifications: **August 15, 2015** Camera-ready: **September 5, 2015**

Call for Papers

IEEE International Conference on Cloud Computing Technology & Science (CLOUDCOM)

Vancouver, BC, Canada, November 30-December 3, 2015

http://2015.cloudcom.org

CloudCom is the premier conference on Cloud Computing worldwide, attracting researchers, developers, users, students and practitioners from the fields of big data, systems architecture, services research, virtualization, security and privacy, high performance computing, always with an emphasis on how to build cloud computing platforms with real impact. The conference is co-sponsored by the Institute of Electrical and Electronics Engineers (IEEE), is steered by the Cloud Computing Association, and draws on the excellence of its world-class Program Committee and its participants. The conference proceedings are published by IEEE CS Press (IEEE Xplore) and indexed by EI and ISSN.

The conference this year solicits research articles in various areas including, but not limited to:

Architecture
* Intercloud architecture models
* Cloud federation & hybrid cloud infrastructure
* Cloud services delivery models, campus integration & "last mile" issues
* Networking technologies
* Programming models & systems/tools
* Cloud system design with FPGAs, GPUs, APUs
* Storage & file systems
* Scalability & performance
* Resource provisioning, monitoring, management & maintenance
* Operational, economic & business models
* Green data centers
* Dynamic resource provisioning

Services & Applications
* Cloud services models & frameworks
* Cloud services reference models & standardization
* Cloud-powered services design
* Business processes, compliance & certification
* Data management applications & services
* Application workflows & scheduling
* Application benchmarks & use cases
* Cloud-based services & protocols
* Fault-tolerance & availability of cloud services and applications
* Application development and debugging tools
* Business models & economics of cloud services

IoT & Mobile in the Cloud
* IoT cloud architectures & models
* Cloud-based dynamic composition of IoT
* Cloud-based context-aware IoT
* Mobile cloud architectures & models
* Green mobile cloud computing
* Resource management in mobile cloud environments
* Cloud support for mobility-aware networking protocols
* Multimedia applications in mobile cloud environments
* Cloud-based mobile networks and applications

Virtualization
* Computational resources, storage & network virtualization
* Resource monitoring
* Virtual desktops
* Resilience, fault tolerance, disaster recovery
* Modeling & performance evaluation
* Disaster recovery
* Energy efficiency

Big Data
* Machine learning
* Data mining
* Approximate & scalable statistical methods
* Graph algorithms
* Querying & search
* Data lifecycle management
* Frameworks, tools & their composition
* Dataflow management & scheduling

HPC in the Cloud
* Load balancing
* Middleware solutions
* Scalable scheduling
* HPC as a Service
* Programming models
* Use cases & experience reports
* Cloud deployment systems

Security & Privacy
* Accountability & audit
* Authentication & authorization
* Cloud integrity
* Cryptography for & in the cloud
* Hypervisor security
* Identity management & security as a service
* Prevention of data loss or leakage
* Secure, interoperable identity management
* Trust & credential management
* Trusted computing
* Usable security

Important Dates
Paper Submissions: **July 8, 2015 (firm deadline)**
PhD Consortium Paper Submissions: **July 15, 2015**
Notifications: **August 15, 2015**
Camera-ready: **September 15, 2015**

Call for Papers

IEEE MASS 2015 Workshop on Content-Centric Networking

in conjunction with IEEE MASS 2015
Dallas, TX, USA, October 19, 2015

http://www.eng.auburn.edu/~szm0001/ccn2015/index.html

Scope

With the exponential growth of content in recent years (e.g., videos) and the availability of the same content at multiple locations (e.g., same video being hosted at Youtube, Dailymotion), users are interested in fetching a particular content and not where that content is hosted. Also, the ever-increasing numbers of mobile devices that lack fixed addresses call for a more flexible network architecture that directly incorporates in-network caching, mobility and multipath routing, to ease congestion in core networks and deliver content efficiently. By treating content as first-class citizen, Content-Centric Networking (CCN) aims to evolve the current Internet from a host-to-host communication based architecture to a content-oriented one where named objects are retrieved in a reliable, secure and efficient manner. CCN has been under active exploration over the past few years, resulting in both clean-slate and overlay architectures and solutions. This workshop will provide researchers and practitioners to meet and discuss the latest developments in this field. The outcomes of this workshop include 1) investigating and understanding some of the challenges in CCN; 2) fostering collaboration among researchers interested in CCN.

In recent years, rapid progress has been made in CCN; multiple initial architectural designs sharing common goals of in-network caching, mobility support and multipath routing have been proposed and prototypes have been implemented. Challenges related to caching and routing of content has received attention. Research areas focusing on what content to cache, how to route for content have been explored, but areas such as security, privacy and economic models for CCN have received limited attention.

The goal of this workshop is to bring together researchers from academia and industry and investigate the architectural issues and challenges in CCN. We invite submissions describing new research contributions including but not limited to the following topics:

- Content-oriented routing protocols
- Content naming
- Scalability issues in CCN
- CCN Architecture design and evaluation
- Security issues in CCN
- Privacy in CCN
- Content centric wireless networks
- Mobility management
- Evaluation of in-network caching techniques
- Limits and limitations of CCN architectures
- Economics and business models
- CCN specific transport protocols
- Specific implementations of CCN architectures

Important Dates

Paper submission: **July 1, 2015**
Paper Acceptance: **July 27, 2015**
Camera-ready paper: **Aug 1, 2015**

Submission Guidelines

Please follow the author instructions at http://www.eng.auburn.edu/~szm0001/ccn2015/index.html

All workshop papers will be included in the IEEE Proceedings.

Steering Committee

Jim Kurose
University of Massachusetts, Amherst, USA
http://www-net.cs.umass.edu/personnel/kurose.html

Workshop Organizers

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Call for Papers

European Conference on Ambient Intelligence (AmI 2015)

Athens, Greece, 11-13 November 2015

http://www.ami-conferences.org/2015

The European Conference on Ambient Intelligence (AmI) is the prime venue for research on Ambient Intelligence with an international and interdisciplinary character. It brings together researchers from the fields of science, engineering, and design working towards the vision of Ambient Intelligence which represents a future where we shall be surrounded by invisible technological means, sensitive and responsive to people and their behavior, deliver advanced functions, services and experiences. Ambient Intelligence combines concepts of ubiquitous technology, intelligent systems and advanced user interfaces putting the human in the center of technological developments.

AmI 2015 welcomes innovative, high quality research contributions advancing the state of the art in Ambient Intelligence. While the conference covers a breadth of AmI-related themes, this year's event pays special attention to the following themes each attracting a growing community of Ambient Intelligence researchers:

- AmI & Healthcare
- AmI & Well-being
- AmI & Social Robots
- AmI & Evaluation
- AmI & City
- AmI & Other Applications
- New & Emerging Topics

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The following Workshops will be organized in the context of AmI 2015 serving as a meeting point, aiming for intensive networking and scientific debate as well as shaping visions of the future:

- WS1: Industrial Human-Computer-Interaction
- WS2: Aesthetic Intelligence
- WS3: Discovery, Exploration and Understanding of Urban Social Context
- WS4: Affective Interaction with Avatars
- WS5: Designing for Ambient Intelligent Lighting

Important Dates

(Full and short papers)

- Submission Deadline: **June 21, 2015**
- Author notification: **July 24, 2015**
- Camera ready deadline: **August 10, 2015**

(Posters)

- Submission Deadline: **July 31, 2015**
- Author notification: **August 25, 2015**

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