Radio Resource Management Strategies for Crowdsourced Journalism Apps

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ABSTRACT

This paper provides a sample of a LaTeX document which conforms, somewhat loosely, to the formatting guidelines for ACM SIG Proceedings. It is an *alternate* style which produces a *tighter-looking* paper and was designed in response to concerns expressed, by authors, over page-budgets. It complements the document *Author's (Alternate) Guide to Preparing ACM SIG Proceedings Using LaTeX2$_\epsilon$ and BibTeX*. This source file has been written with the intention of being compiled under LaTeX2$_\epsilon$ and BibTeX.

The developers have tried to include every imaginable sort of "bells and whistles", such as a subtitle, footnotes on title, subtitle and authors, as well as in the text, and every optional component (e.g. Acknowledgments, Additional Authors, Appendices), not to mention examples of equations, theorems, tables and figures.

To make best use of this sample document, run it through LaTeX and BibTeX, and compare this source code with the printed output produced by the dvi file. A compiled PDF version is available on the web page to help you with the 'look and feel'.

Categories and Subject Descriptors

H.5.1 [**Information Interfaces and Presentation**]: Multimedia Information Systems—*Video*; C.2.1 [**Computer-Communication Networks**]: Network Architecture and Design—*Wireless Communication*

General Terms

Design, Performance, Theory

Keywords

Mobile video, streaming, cellular, LTE

MoVid '14, March 19, 2014, Singapore.

1. INTRODUCTION

Using video streaming technologies, media broadcasters can now offer multiple live TV programs in parallel. This feature enables in particular local news broadcasters to cover multiple simultaneous local events, *e.g.*, a regional sport tournament for kids and a political meeting. Each local event is not expected to attract a large population, but a catalog of local events can consolidate a wide audience. However media companies can hardly pay for the coverage of many simultaneous events. An idea is to let attendees of the event act as journalists and cover the event from their smart devices (smartphone or connected cameras). The concept of *crowdsourced journalism* [9] has emerged from both recent technological advances (high-performances cellular network and smart devices) and the willingness of users to cover events. Crowdsourced journalism has also demonstrated its interests in the case of unexpected events, which can be covered by witnesses without delay, *e.g.* the crash of a plane.

In a recent experiment, we proposed a set of people to cover a local event [9]. Each "journalist" was equipped with a mobile phone and was invited to send live video stream to a server through a Long Term Evolution (LTE) cellular network. One of the main observations we made was that journalists are likely to cover the same scene within the local event, typically the presence of a celebrity among the attendees. This behavior puts an important stress on the network infrastructure because multiple mobile users are in the same network cell when they transmit their live videos. Theoretically, LTE supports overall uplink throughput rates of 75 Mbps [2], limiting the possible number of journalists able to cover a scene with decent quality video. Therefore, the first major challenge in this scenario comes from the limitation of bandwidth. Besides this, when there are large amount of data transferred in a wireless network, the network delay may be increased significantly and become intolerable. Therefore, efficient wireless resource management methods are required in this scenario to provide Quality-of-Service (QoS) guarantee for the transmission of live video streams.

To meet the increasing traffic demand in 3GPP LTE networks, Heterogeneous Network (HetNet) is widely accepted as a promising technique [8]. With this proposal, the cell is delimited by a macro Evolved Node B (eNodeB), which ensures the coverage to meet the demands of low speed

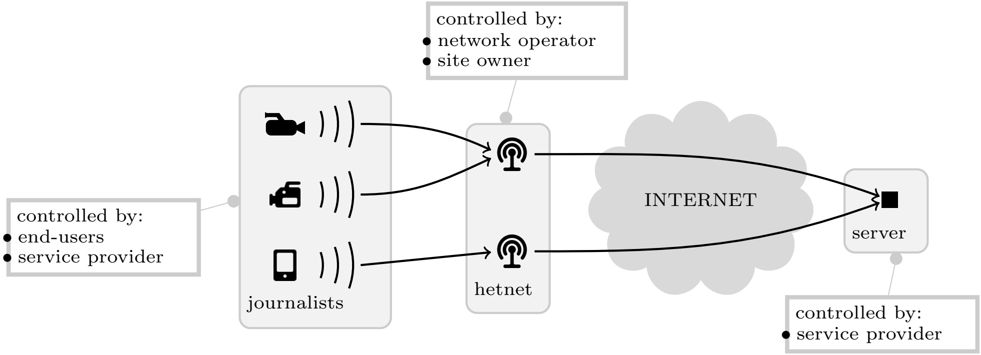

Figure 1: The delivery chain for uploaders in cellular networks

services, and within the cell, the radio access network is enhanced by multiple pico eNodeB, which guarantee the hotspot coverage for capacity enhancements.

In this article, we consider the overall delivery chain of crowdsourced journalism depicted in Figure 1. On the left, journalists capture an event from a smart camera (*e.g.*, a camera integrated on a smartphone, connected glasses, and a connected camera). The journalists are end-users, who have the control of their devices. However, they usually run an application that has been implemented by a service provider, which controls key parameters of the transmission, including the encoding parameters (resolution and rate) of the video stream. Data flows are sent to eNodeBs in the HetNet. Network operators are in charge of installing, configuring, and maintaining the macro eNodeBs. However, today's pico eNodeBs are controlled by third parties. Without loss of generality we speak of *site owners* to refer to the ones who make the placement and physical configurations of pico eNodeBs. At the end of the chain, the service provider receives the streams, which can then be widely delivered using regular content delivery technologies. In this process, it is necessary to consider that wireless networks are not always reliable to gurantee video service delivery due to propagation effects of wireless channels, and traffic load variations affecting both the resource sharing within a serving cell and the interference across neighboring cells. Therefore, the eNodeBs have to guarantee the QoS of live streaming transmissions with proper radio resource management (RRM) decisions such as cell association, resource allocation and power control.

The scope of this article is hence to examine how operators can manage RRM strategies so as to make mobile users enjoy crowdsourced journalism applications reliably. The rest of the paper is organized as follows...

2. RRM CHALLENGES IN HETNETS FOR CROWDSOURCED JOURNALISM

Typically, pico eNodeBs are placed at strategic points with the goal of improving the throughput. However, this can only be achieved if both the available resources at the pico eNodeBs and the interferences generated by these nodes are correctly managed. Therefore, intelligent cell association, resource allocation, power control and interference management schemes are needed to achieve gains in performance, and the interplay between these scheems have to be studied carefully [5, 6].

2.1 Cell Association Policy

In a HetNet scenario it is possible that a user is covered simultaneously by the macro eNodeB and a pico eNodeB. The cell assocation policy has to decide to which eNodeB this user should be associated. This policy is implemented on the eNodeBs through an algorithm, which can be updated by network operators. This algorithm is not expected to be performed very often, but only when the conditions have significantly changed.

Compared with homogeneous networks, HetNets are much more sensitive to the cell association policy because of the massive disparities in cell sizes. In the first ones, a mobile device is associated with the eNodeB whose signal is received with the largest average strength. However, in a HetNet scenario this strategy could lead to a load imbalance between the macro and pico eNodeBs, limiting the mobile device throughput.

Many association rules have been proposed for HetNets [4, 10]; however, it is not clear which one is the best option since each study is based on a different resource allocation scheme and a different set of assumptions. In this work, the goal will be to associate mobile devices to one of the macro or pico eNodeBs in order to maximize the sum rate or minimum rate of all mobile devices.

2.2 Resource Allocation Policy

Single-Carrier FDMA (SC-FDMA) has been selected as radio access technology for LTE uplink (UL) [1]. The spectrum available at each eNodeB is divided into M resource blocks (RBs), each one consisting of 12 adjacent subcarriers, with a bandwidth of 180 kHz, and with a total time duration of 1 ms. LTE UL subsystem has two inherent constraints: contiguity constraint and robust rate constraint. The contiguity constraint means that RBs have to be allocated to a single mobile device in a contiguous manner [11]. On the other hand, the robust rate constraint is that mobile device must adopt the same modulation and coding scheme for all allocated RBs [12].

Resource allocation, which is also a piece of software that can be updated by network operators, decides which mobile device is going to transmit on each RB in a cell. Therefore, user throughput will depend on the number of users associated with the same eNodeB as well as the user scheduling policy implemented. The previous contiguous allocation constraint limits the scheduling flexibility and makes the resource allocation be NP-hard. Therefore, the proposed scheduling algorithms are often based on heuristics yielding reasonable system performance under practical circumstances [1].

In this work, we are going to consider long-term periods in the order of seconds. This allows us to integrate our proposal with any of the state-of-the art schedulers for LTE uplink without the need to modify the scheduling mechanisms already deployed. Our objective is thus to determinate the average resource share (i.e., RBs) of each user.

2.3 Power Control Policy

Power control determines the amount of power allocated to each scheduled mobile device on the allocated resources. Since our work is focused on the transmission of live video streams to the system, we will focus on the uplink power control mechanisms.

In 3GPP LTE, Fractional Path Loss Compensation Power Control (FPC) mechanism is used for uplink power control, which is open-loop and based on the path loss measurement done by the mobile device but controlled with a factor α by the network. Meanwhile, a closed-loop power control mechanism can also be applied, where measurements by the eNodeBs are used to generate transmit power control commands that are send to the mobile devie as part of the downlink control signalling.

In this work, the approach that we use is similar to the one presented in [13], where power control is simplified by ignoring closed-loop corrections. Then, the total transmission power of user i towards eNodeB j is calculated as

$$P_{ij} = min\{P_{max}, P_0 + 10log_{10}m_{ij} + \beta L_{ij}\} \qquad (1)$$

where P_{max} is the maximum UE transmission power level, P_0 is a cell specific parameter that defines the UE minimum transmission power, m_{ij} is the number of RBs that are allocated to user i, L_{ij} is the downlink propagation loss that is measured by the mobile device and β represents a compensation factor for the path loss. In addition, it is also considered that the total transmission power of a mobile device is shared equally among all the RBs allocated to this mobile device.

2.4 Interference Management Policy

Another key policy is the management of interferences. This problem has been extensively studied in the context of homogeneous cellular networks. In this scenario, if several base stations are located close enough, they can interfere among them. However, in HetNet, in order to better reuse the limited radio resources, it is possible that the pico eNodeBs utilize the same spectrum allocated to the macro eNodeBs and therefore they interfere with each other.

Orthogonal Deployment (OD) and *Co-Channel Deployment (CCD)* have been proposed in 3GPP to share resources between macro and pico eNodeBs [3]. OD mitigates interference among macro and pico eNodeBs allocating orthogonal RBs. The macro eNodeB uses $M - K$ RBs, while pico eNodeBs share the other K RBs. These K RBs are usually divided among the pico eNodeBs based on the conventional frequency resue [7], i.e., given reuse factor u the K RBs are equally divided among the pico eNodeB such that each pico BS is granted a group of K/u eNodeBs and co-channels pico eNodeBs using the same group of sub-channels. On the other hand, in CCD all eNodeBs use all the available M RBs. This solution is considered more eficient for systems with limited spectrum since it avoids spectrum partitioning.

3. SYSTEM MODEL

In this work we develop a unified framework to analyze, compare, and evaluate the performance of the different policies presented in the previous section. Although our framework is centralized and static, since we consider a snapshot of the system both in terms of user deployment and channel gains, it will allow us to perform an offline study of different combinations of the previous policies to select the best performing ones.

We consider a communication system composed of one macrocell (cell $j = 1$) overlaid with $B - 1$ picocells (cells $j = 2, ..., B$) that are identical in terms of antenna gain and backhaul capacity. The set of eNodeBs is denoted by $\mathcal{B}$. There are N fixed users in the sytem. The set of users is denoted by $\mathcal{N}$. Each user can associate with only one eNodeB. Let $x_{ij} = 1$ if user i is associated with BS j, and let it be 0, otherwise. Let α_{ij} be the proportion of RB that user i is scheduled on the uplink by eNodeB j.

Path losses are modelled using the same model as in [5]:

$$L_{ij} = \begin{cases} 128 + 37.6log_{10}(d_{ij}/1000), & \text{if } j = 1, \\ 140.7 + 36.7log_{10}(d_{ij}/1000), & \text{if } j \neq 1, \end{cases} \quad \forall i \in \mathcal{N}, \qquad (2)$$

where d_{ij} represents the distance between user i and eNodeB j in meters. Then, the gains can be calculated as:

$$G_{ij} = \begin{cases} g_u \times g_m \times L_{ij}, & \text{if } j = 1, \\ g_u \times g_p \times L_{ij}, & \text{if } j \neq 1, \end{cases} \quad \forall i \in \mathcal{N}, \qquad (3)$$

where g_u represents the mobile device antenna gain, and g_m and g_p represent the marcro and pico antenna gains, respectively.

The SINR of user i at eNodeB j on each RB (c) can be written as:

$$\gamma_{ij}^{(c)} = \frac{P_{ij}^{(c)} \times G_{ij}}{N_0 + I_{ij}^{(c)}}, \ \forall i \in \mathcal{N}, \forall j \in \mathcal{B}, \text{ and } \forall c \in \mathcal{M}, \qquad (4)$$

where N_0 is the additive white Gaussian noise power, $I_j^{(c)}$ is the interference level on uplink RB c of eNodeB j, and $P_{ij}^{(c)}$ is the transmission power on RB c of user i towards eNodeB j, which is calculated as follows:

$$P_{ij}^{(c)} = P_0 + \beta L_{ij} \qquad (5)$$

assuming a scenario where the path loss are not going to saturate the maximum transmission power allowed at each RB, i.e., P_{max}/m_{ij} (due to the equal sharing assumption for the transmission power).

In this work, $\gamma_{ij}^{(c)}$ will not depent on the RB c between user i and eNodeB j, due to two reasons. First of all, it is assumed that the total transmission power of a user is shared equally among all its allocated RBs. In addition to this, it is also assumed a uniform level of interferences over the set of RBs of a eNodeB. Therefore, the channel capacity per RB can be calculated using the Shannon-Hartley theorem as:

$$K_{ij} = b \times log_2(1 + \gamma_{ij}), \ \forall i \in \mathcal{N}, \text{ and } \forall j \in \mathcal{B}, \qquad (6)$$

We are going to explore this scenario from an optimization standpoint. Several optimization problems are going to be formulated and solved in a static case. With this study, we will be able to estimate what can be theoretically obtained with proper RRM estrategies, and it will help us to select the best performing ones.

4. PROBLEM FORMULATION

We study in this paper the actions that network operators can take to improve the performances of the system. Various objectives can be considered. We focus here on two goals:

- We fix a video stream bit-rate, which is the same for every journalists. *Uploading journalists* are the journalists with uplink throughput above this fixed rate. Our goal is to *maximize the number of journalists who can simultaneously transmit a video stream of decent quality.*
- We define a set of possible encoding bit-rates. Each uploading journalist emits a stream to the maximum bit-rate smaller to her uplink throughput. Our goal is to *maximize the sum of all bit-rates of emitted video streams.*

4.1 Co-Channel Deployment

Assuming a Co-channel deployment (CCD) means that all the RBs are shared among all the eNodeBs. In this case, an average level of interferences is going to be assumed at each RB, independently of the eNodeB. This value is obtained from the simulation results presented in Section 5.

4.1.1 Scenario 1

The problem is of optimal cell association (x_{ij}) and resource allocation (α_{ij}). In the first scenario, the objective is to maximize the minimum throughput (λ_i) of all the users.

$$\max_{\{x_{ij}\},\{\alpha_{ij}\}} \min_{i\in\mathcal{N}}(\lambda_i) \tag{7a}$$

$$\text{s.t.} \qquad \lambda_i = \sum_{j\in\mathcal{B}} M\cdot\alpha_{ij}\cdot K_{ij},\ \forall i\in\mathcal{N}, \tag{7b}$$

$$P_0 + 10log_{10}(M\alpha_{ij}) + \beta L_{ij} \le P_{max},\ \forall i\in\mathcal{N},\text{ and }\forall j\in\mathcal{B}, \tag{7c}$$

$$\sum_{i\in\mathcal{N}} \alpha_{ij} \le 1,\ \forall j\in\mathcal{B}, \tag{7d}$$

$$\sum_{j\in\mathcal{B}} x_{ij} = 1,\ \forall i\in\mathcal{N}, \tag{7e}$$

$$\alpha_{ij} \le x_{ij}, x_{ij}\in\{0,1\},\ \forall i\in\mathcal{N},\text{ and }\forall j\in\mathcal{B}. \tag{7f}$$

4.1.2 Scenario 2

In this scenario the system throughput is maximized, considering that each user uploads with a minimum threshold.

$$\max_{\{x_{ij}\},\{\alpha_{ij}\}} \sum_{i\in\mathcal{N}} \lambda_i,\ \forall i\in\mathcal{N}, \tag{8a}$$

$$\text{s.t.} \qquad \lambda_i = \sum_{j\in\mathcal{B}} M\cdot\alpha_{ij}\cdot K_{ij},\ \forall i\in\mathcal{N}, \tag{8b}$$

$$\lambda_i \ge threshold,\ \forall i\in\mathcal{N}, \tag{8c}$$

$$P_0 + 10log_{10}(M\alpha_{ij}) + \beta L_{ij} \le P_{max},\ \forall i\in\mathcal{N},\text{ and }\forall j\in\mathcal{B}, \tag{8d}$$

$$\sum_{i\in\mathcal{N}} \alpha_{ij} \le 1,\ \forall j\in\mathcal{B}, \tag{8e}$$

$$\sum_{j\in\mathcal{B}} x_{ij} = 1,\ \forall i\in\mathcal{N}, \tag{8f}$$

$$\alpha_{ij} \le x_{ij}, x_{ij}\in\{0,1\},\ \forall i\in\mathcal{N},\text{ and }\forall j\in\mathcal{B}. \tag{8g}$$

4.1.3 Scenario 3

In this scenario there is a set $\mathcal{R}$ composed by R predefined bitrates ($R_1 = 7kbps$, $R_2 = 500kbps$, $R_3 = 900kbps$), and the number of users that are uploading content according to the previous bitrates is U_1, U_2 and U_3. A new decision variable β_{it} is defined, which represents the bitrate t assigned to each user i.

$$\max_{\{x_{ij}\},\{\alpha_{ij}\},\{\beta_{it}\}} \sum_{t\in\mathcal{R}} U_t\cdot R_t \tag{9a}$$

$$\text{s.t.} \qquad \lambda_i = \sum_{j\in\mathcal{B}} M\cdot\alpha_{ij}\cdot K_{ij},\ \forall i\in\mathcal{N}, \tag{9b}$$

$$P_0 + 10log_{10}(M\alpha_{ij}) + \beta L_{ij} \le P_{max},\ \forall i\in\mathcal{N},\text{ and }\forall j\in\mathcal{B}, \tag{9c}$$

$$\sum_{i\in\mathcal{N}} \alpha_{ij} \le 1,\ \forall j\in\mathcal{B}, \tag{9d}$$

$$\sum_{j\in\mathcal{B}} x_{ij} = 1,\ \forall i\in\mathcal{N}, \tag{9e}$$

$$\sum_{t\in\mathcal{R}} \beta_{it} = 1,\ \forall i\in\mathcal{N}, \tag{9f}$$

$$\lambda_i \ge \sum_{t\in\mathcal{R}} \beta_{it}\cdot R_t,\ \forall i\in\mathcal{N}, \tag{9g}$$

$$U_t = \sum_{i\in\mathcal{N}} \beta_{it},\ \forall t\in\mathcal{R}, \tag{9h}$$

$$\beta_{it}\in\{0,1\},\ \forall i\in\mathcal{N},\text{ and }\forall t\in\mathcal{R}, \tag{9i}$$

$$\alpha_{ij} \le x_{ij}, x_{ij}\in\{0,1\},\ \forall i\in\mathcal{N},\text{ and }\forall j\in\mathcal{B}. \tag{9j}$$

4.2 Orthogonal Deployment

The Orthogonal Deployment studied in this paper is performed with no frequency resue. It means that the total number of available RBs in the uplink (M) are divided over the set of eNodeB with no overlapping. By this way, the uplink transmissions of the different mobile devices are not going to interfere among them. This strategy is suboptimal because it prevents two pico eNodeBs to use the same band although they may be far enough to not interfere. Yet, it has key advantages in practice, since it does not require specific configurations on every site.

The evaluations of the previous scenarios with this interference management policy is similar to the previous one. However, here it is necessary to consider that there are not interferences ($I_j^{(c)} = 0$), and the value of M is shared over the set of eNodeBs ($M = \sum_{j\in\mathcal{B}} M_j$).

5. NUMERICAL RESULTS

Here is a glimpse of the results we can achieve by using CPLEX.

6. RELATED WORKS

Cell Association: [5, 10, 4]
Resource Allocation: [1, 13]
Interference Management: [3, 5]
To be completed...

7. CONCLUSIONS

8. ACKNOWLEDGMENTS

This section is optional; it is a location for you to acknowledge grants, funding, editing assistance and what have you. In the present case, for example, the authors would like to thank Gerald Murray of ACM for his help in codifying this *Author's Guide* and the **.cls** and **.tex** files that it describes.

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