Review of Power Control Mechanisms in Cellular System

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Abstract

Here an advanced tutorial on power control issues in all generations of cellular system has been presented. Power control represents a key degree of freedom in design of cellular system, offering substantial benefits for efficient and fair of operation of the system, especially in energy efficient designs. It also supports several functionalities including QoS, bit error rate optimization and energy efficient designs in all stages of cellular system. Taking energy efficiency into account, performance of different power control algorithms have been analyzed as a function of transmitted power with some interesting results.

Index terms— power control, cellular networks, 2G, 3G, QoS.

1 Introduction

ith the rapid development of information & communication technologies (ICT) particularly the wireless communication technologies, the energy consumption has grown up to 163 PJ that leads to emission of around 32.9 million tones of CO 2 & it is around 2% of worldwide CO 2 emission [1][2][3]. With the increasing demand for wireless services and ongoing 3G, upcoming 4G, the subscriber base is expected to be more than one billion. This growth will require 1, 00,000 more stations to ensure network availibity [2]. Due to rapid increase in number of users, it is causing burden on network operators form economical perspectives and environmental perspectives. Economical perspectives in terms power consumption. A fundamental component of radio resource management is transmitter power control. It is well known that minimizing interference using power control increases capacity [4] and also extends battery life.

Considering this factor, it becomes quiet necessary to study the power allocation and power control schemes adopted in all generations of cellular system. This paper surveys and gives overviews of power allocation and distribution/control schemes. Power control mechanisms have played an important role in the success of digital cellular system. Power control offers substantial benefits for the efficient and fair operation of the cellular system, supports QoS adaption Like rate control [5], bit error rate and energy efficient design in all stages of cellular system. Power control has mainly used to guarantee the signal interference ratio of an ongoing connection resulting in a higher utilization of quality of service [6]. power control was, is and (we strongly believe that it) will remain one of the most important radio resource management techniques in wireless networks, as it mitigates the consequences of two fundamental limitations of wireless networks as Radio spectrum, though non exhaustible, is both a limited and-often-underutilized resource. This makes interference and interference mitigation critically important for wireless networks and Mobile wireless devices, such as mobile phones, Personal Digital Assistants (PDAs) etc., have significant limitations on the duration of their "talk time," as the "life" of their battery is limited. As technology improvements in the direction of prolonging battery life are slower than advances in communications, this constraint continues to have dramatic impact, particularly for uplink transmissions (from mobile nodes to base stations) [7].

The reminder of this paper is organized as follows, in section II we present the different power allocation schemes used in cellular system. In section III we will discuss about power control schemes adopted in all generations of cellular system. Results on different power control mechanisms also presented in section IV in terms of energy efficiency. Finally conclusions of the survey are presented in section V.

2 II.

3 Power Allocation / Control Schemes in Cellular System

Transmission power represents a key degree of freedom in the design of wireless networks. In both cellular and ad hoc networks, power control helps with several functionalities like interference management due to broadcast nature of wireless communication ,signal interfere with each other, energy management due to limited battery power in mobile terminals or any handheld devices and connectivity management. Equal bit energy strategy implies the received SIR is the same for all types of media at one time instant. This scheme doesn't balance well the natural dissimilarity between voice and data traffic. In our multi-media system high-rate data traffic with lower BER requirements and lower-rate voice traffic with higher BER requirements are transmitted through the same channel. Clearly, the interference that voice users can tolerate and the one that data users can tolerate are different. Moreover the interference that data users cause to voice users is also different from the interference that voice users cause to data users. Hence the performance of the more vulnerable traffic may degrade drastically when the user number is increased [8].

4 b) Adaptive Power Allocation Schemes

The difference between adaptive power control and fixed power allocation lies in the dynamic power allocation during a dynamic traffic situation. With fixed power allocation the allocated power level is fixed for each type of media, no matter what kind of traffic profile it is. While with adaptive power allocation, the target power level is changed as traffic load changes. However the decision of power allocation is done on the basis of traffic pay load i.e. either strength based optimal power allocation scheme, with this strategy, strength-based power control is used for individual traffic. At the mean time, traffics are grouped into two groups according to its priority. Those media with a set maximum allowed BER are media with high priority, and media without set maximum are media with low priority. The proposed power control method is to maximize throughput or minimize BER of media with low priority while maintaining the required BER of media with high priority or strength and SIR-based optimal power allocation scheme, this Scheme [8] uses strength based power control for data users and SIR-based power control for voice users. The objective is to always guarantee to meet the minimum required voice quality and reserve the highest possible system capacity to data users. In other words, the system adjusts the relationship between data users and voice users according to the system traffic load in order to make the BER of voice users equal to the required value. This scheme outperforms equal bit-energy strategy in both nonfading and fading channel. Besides, this scheme can take advantage of graceful degradation characteristics, so that the system can accommodate more users with just a little bit performance degradation **??**8 & 9].

5 c) Canonical Power Control Scheme

A more general framework on convergence analysis is given that builds on the standard interference function in [10]. The authors define a broader class of synchronous and totally asynchronous power control algorithms known as the canonical algorithms.

6 d) Stochastic Power Control Scheme

There are two types of stochastic dynamics often modeled in wireless cellular networks [5]. One is channel variations and the other is user mobility. Robustness against these dynamics has been analyzed and algorithms leveraging them have been designed. In this [5] a stochastic approximation based, on-line algorithm for controlling transmitter powers, using a fixed step size that provides weak convergence and faster response to time-varying channel conditions has been proposed.

7 e) Binary Power Control Scheme

Binary power control is a power control scheme with only two allowable power values, usually P min (0) or P max (1). Hence a link can either transmit at a full power or be switched off completely. Binary power control (BPC) has the advantage of leading towards simpler or even distributed power control algorithms. For N > 2 we propose a strategy based on checking the corners of the domain resulting from the power constraints to perform BPC. We identify scenarios in which binary power allocation can be proven optimal also for arbitrary N [11,12] asP min ?P?P max**(1)**

III.

8 Power Control in all Generations of Cellular System

Power control implementations in cellular systems often consist of Open-loop power control (OLPC) and Closed-loop power control (CLPC). The closed loop power control accomplishes close estimate to the desired level at the receivers of mobile stations. The receivers constantly observe the received signal quality (may be reflected by signal strength, i.e. signalto-interference ratio (SIR), bit error rate (BER), and delay) and determine appropriate power control commands. A feedback channel is necessary to transmit these commands to the senders for power adjustments. The open loop power control does not need a feedback channel. The transmitting power level adjustment is determined based on the estimation of the channel quality of the opposite direction stations. The estimation error of the open loop power control can be rather high, especially when the forward link and the reverse link are not highly correlated. The 2G systems were primarily designed for voice which is generated at a fixed bit rate, and the power control mechanisms were geared towards targeting a fixed SIR, determined by the quality of voice that needs to be supported. The GSM [13] based 2G standard is an orthogonal scheme where the MSs within a sector are allocated a separate time and frequency slot for both uplink and downlink. Maintaining orthogonality between MSs of the same sector implies that the time-frequency resource for each MS is limited and the SIR requirement for voice communication is higher in comparison to IS-95. These rules out frequency reuse of one in GSM systems. The nonexistence of inter-sector interference from the immediate neighbors of a sector and the non-existence of intra-cell interference due to the orthogonality of MSs within a sector imply that the need for CLPC in GSM standard is less in comparison to IS-95. As such, GSM implements a CLPC scheme both on the uplink as well as the downlink with updates every 480ms based on two parameters referred to as ”RxLev” and ”RxQual”. The ”RxLev” is the receive power level and the ”RxQual” is the receive signal quality in terms of SIR or BER.

The base station controls the power output of the mobile, keeping the GSM power level sufficient to maintain a good signal to noise ratio, while not too high to reduce interference, overloading, and also to preserve the battery life. A table of GSM power levels is defined, and the base station controls the power of the mobile by sending a GSM ”power level” number. The mobile then adjusts its power accordingly. In virtually all cases the increment between the different power level numbers is 2dB.The accuracies required for GSM power control are relatively stringent. At the maximum power levels they are typically required to be controlled to within +/-2 dB, whereas this relaxes to +/-5 dB at the lower levels. a) Power control in 3G networks Qualcomm proposed an OLPC scheme for a CDMA based cellular system where the transmit power is set inversely proportional to the received power [14]. The OLPC scheme was augmented by a CLPC scheme where they receive powers were equalized through a 1bit feedback [15]. This power control solution to the near-far problem was instrumental in enabling the success of CDMA networks.

In [16] author has proposed an algorithm based on an adaptive modification of the transmitted power update step size. In this, the Adaptive-Step Power Control Algorithm, which could be easily implemented, is an interesting variant of the one-bit command PC of WCDMA System. The quicker convergence of the proposed ASPC (with regard to the present version of power control in WCDMA) may give a capacity increase.

9 b) Power Control in Wi-Fi Networks

The 802.11 standard implements a MAC algorithm that involves carrier sense and exponential back off and does not dictate any explicit power control scheme. Researchers have attempted to remedy the situation by proposing various MAC layer schemes that can be implemented on top of the PHY layer. One such mechanism is for the receiver to send back the power level of data transmission in a control channel at the maximum power, in response to intention of data transmission indicated by the transmitter. However, transmitting data and control channel at different power levels results in inefficient operation in an unplanned spread of APs. Improvements to this scheme were suggested in [17] to get around the problem by occasionally transmitting data at the maximum power to prevent neighboring APs from taking over the channel.

10 IV.

11 Results and Discussion

Based on the different power control schemes presented in above section, we will investigate the performance considering a binary power control scheme assuming a signal undergoes various radio propagation uncertainties. However the performance is measured in terms of energy efficiency which is quiet closely related with power distribution and can be expressed as, Where ? is the energy efficiency, S i is the received signal and ?? ?? is the AWGN in wireless sub-channel.

Fig. 3 shows the energy efficiency comparison of EEBPCB [3], BPC [12] and EEBPC algorithm [19] and average power control algorithm [18] as a function of total transmitted power. Here as the signal transmitted power increase, the energy efficiency goes on decreasing. However BPC, EEBPC and EEBPCB algorithms shows significant improvement in energy efficiency in comparison with average power control algorithm.

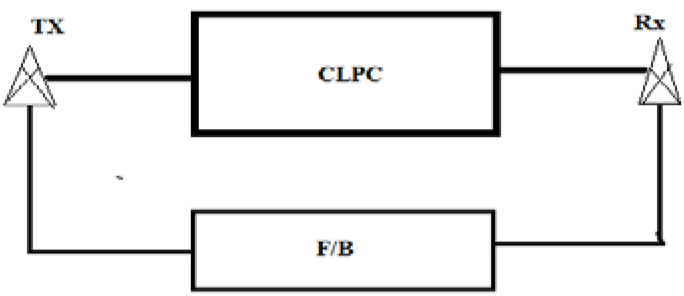
12 Conclusion

This paper provides an overview of the different power allocation schemes adopted in cellular system along with power control mechanisms. The exact impact of the power control mechanisms has been analyzed. By reviewing some fundamental approaches, we have presented results showing the exact impact of the power control schemes on the design of energy efficient design. Energy survey [18] EEBPCB [3] BPC [12] EEBPC [19] 14. S. K. Gilhousen, R. Padovani, and C. E. Wheatley., ”Method and apparatus for controlling transmission power in a CDMA cellular mobile telephone system,” United States Patent 5,056,109, October 1991. [1]

Figure 1: I

1

Figure 2: Fig. 1 :F



2

Figure 3: Fig. 2 :

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Power level No.	Power level output DBM		
	GSM 900	GSM 1800	GSM 1900
2	39	26	26
3	37	24	24
4	35	22	22
5	33	20	20
6	31	18	18

Figure 4: Table 1 :

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