



An intelligent scheduling scheme for real-time traffic management using Cooperative Game Theory and AHP-TOPSIS methods for next generation telecommunication networks



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ABSTRACT

The emerging and exponential growth of telecommunication networks have developed a variety of smart and powerful devices to handle a wide range of multimedia applications such as Voice over IP (VoIP), video streaming, etc. 3GPP introduced Long Term Evolution (LTE) in release 8 and LTE-Advanced (A) in release 10 to support multimedia traffic as these technologies offers high data rate, high bandwidth, and low latency. It also created new challenges to handle resource allocation and power optimization of User Equipment (UE). The paper explores radio resource allocation and power consumption problem of UE in LTE environment. An intelligent scheduling scheme developed is based on Cooperative Game Theory (CGT) method and AHP-TOPSIS method. It distributes resources in a fair way among a number of applications and UE are prioritized based on certain criteria like delay, throughput history, UE buffer space and channel conditions and preferences. In LTE, Discontinuous Reception (DRX) has been adopted to conserve the battery life of UE. DRX periodically switches off the radio interfaces to conserve the battery life but it may breach Quality of Service (QoS). Therefore, the DRX parameters need to be further optimized to satisfy QoS and minimize power consumption of UE. DRX parameters are dynamically adjusted on the basis of current load and channel condition of the network. Power saving operations are numerically analyzed. Simulation results show that the expert and an intelligent system can distribute resources in a fair way among UE, improves the battery consumption of UE up to 85% and packets transmission delay by 10% as compared to existing scheme for real-time applications.

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1. Introduction

Nowadays, a variety of smart and powerful devices are developed to support the wide range of multimedia traffic such as Voice over IP (VoIP), instant messaging, video streaming, etc. Third Generation (3G) network does not have the capability to handle these applications effectively because they require high data rate, low latency and high bandwidth. To satisfy the demand, Third Generation Partnership Project (3GPP) introduced Long Term Evolution (LTE) in release 8 and LTE-A in release 10 to support multimedia traffic as it offers high data rate, bandwidth, and low latency. The main component of LTE is evolved node (eNB). It provide air interface between user plane and control plane. eNB handles radio communication between UE in a cell and carries out mobility decision and radio resource management. LTE support Orthogonal

Frequency Division Multiplexing (OFDM) to avoid inter-symbol interference, Multiple-Input Multiple-Output (MIMO) to boost up the data rates and these techniques are complex in nature (Akyildiz, Gutierrez-Estevez, & Reyes, 2010). Due to this high complexity, the power consumption of User Equipment (UE) is high, and in telecommunication systems, power optimization is the one of the main challenges.

Global System for Mobile (GSM), Universal Mobile Telecommunication System (UMTS) introduced the concept of Discontinuous Reception (DRX) for saving battery life of UE (Yang & Lin, 2005). But in UMTS, only two stages such as inactivity timer and DRX cycle have been introduced for wake-up and sleep period. LTE adopted DRX and introduces light sleep and deep sleep mode to conserve more power. In light sleep mode, UE stays in sleep mode for the smallest period of time and longer in deep sleep mode. But if any packet arrives at sleep mode, it would pose unexpected delay. This affect the Quality of Service (QoS) of the network as multimedia traffic is delay-sensitive in nature. Tseng et al. (2016) analyzed power saving using DRX by considering recursive deduction,

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Markov model, etc. The result showed that proper choice of parameters could reduce the battery consumption of UE. Nowadays as the usage of real-time and other applications is increasing, there is further need to maximize the power saving so that end users can get effective services without affecting QoS.

During the last decade, the number of optimization techniques is used for improving algorithms, conception, etc. Inwhee, Won-Tae, and Seokjoon (2008) proposed network selection algorithm by using AHP method. It predicted the battery consumption of UE in a selected network. Senouci, Mushtaq, Hoceini, and Mel-louk (2016) used TOPSIS method for selection of mobile network interface in the dynamic condition of the network. Resource allocation based on game theory was also proposed and showed that bandwidth could be shared among different coalitions of applications (Park & van der Schaar, 2007). Jin and Qiao (2012) introduced a method for modeling DRX parameters in LTE networks. This scheme analyze the power saving factor and transmission delay of packets. But the paper does not consider dynamic behavior of the network. It can affect the QoS of network since load keeps on changing. Therefore, the DRX parameters need to be further optimized. We have not found any study which focuses on scheduling scheme along with adjustment of on-duration time according to the dynamic nature of networks. It results in effective scheduling mechanism that can help to reduce power consumption of user devices.

In this paper, an intelligent scheduling scheme is proposed that conserves the battery life of UE and provide better QoS in LTE-A environment. The proposed algorithm is divided into two parts. In the first part, the scheduling algorithm is proposed and optimized based on Cooperative Game Theory (CGT) and AHP-TOPSIS methods. Based on these techniques resources are distributed in a fair way among the number of applications and prioritize the UE based on certain criteria and preferences. UE are prioritized based on the parameters like delay, buffer length, throughput history, channel quality. In the second phase of the approach, the power saving operations are numerically analyzed in dynamic conditions of the network, so that on-duration of UE is adjusted accordingly. The proposed scheme improves the power saving factor and transmission delay as compared to the scheme proposed by Jin and Qiao (2012).

The rest of the paper is organized as follows: Section 2 describes the background of DRX, essential parameters required for scheduling and its related work. Section 3 presented the proposed scheme. In Section 4, proposed computational model is described. In Section 5, results are numerically analyzed and Section 6 concludes the paper.

2. Background and its related issues

In this section, the background of DRX, scheduling scheme, essential parameters and its related work is discussed.

2.1. Background of DRX

3GPP introduced DRX in UMTS in Release 7 and it was just two step operation, i.e., ON and OFF. When there is any packet to traverse, DRX gets ON otherwise it remains in OFF mode (Yang & Lin, 2005). These two steps are extended to three steps in LTE for more power saving during inactivity timer and introduced light sleep and deep sleep modes. LTE uses Radio Resource Control (RRC) as an air interface for connection establishment and release. There are two states of RRC, i.e., RRC_idle and RRC_Connected and DRX work in these states (Bontu & Illidge, 2009). LTE adopted DRX to conserve the battery power of UE. In RRC_idle state, UE switches to off mode but remain registered with the network through unique identifier. In RRC_Connected mode, UE remains in active state and

can traverse data packets. UE can conserve more power by switch off its radio interfaces when there is no packet to traverse. The notation of DRX is defined as following and is shown in Fig. 1.

- On-duration: It is the time when UE monitors the packets on Physical Downlink Control Channel (PDCCH) and remain in the active state. When UE come in active mode, inactivity timer gets started.
- Inactivity timer: During on-duration, if there is any packet listen on PDCCH, UE starts its inactivity timer and receives packets. If any other packet arrives before the expiration of inactivity timer, the inactivity timer restarts itself to receive packets. After the expiry of inactivity timer, UE starts DRX cycle and comes into the sleep state.
- Sleep state: While monitoring the PDCCH, if UE does not sense arrival of any packet then UE remains in the sleep state. There are two types of sleep mode: light sleep and deep sleep. In light sleep mode, UE wakes up frequently for a very short period of time and listen to PDCCH. If no packet listens through PDCCH then it again goes back to sleep mode. In this mode, UE consumes very less battery. But in deep sleep mode, UE remain in sleep mode for the longest period of time. UE wake up again after the expiration of deep sleep timer and does not consume power.

The previous research focussed on how to adjust DRX parameters so as to minimize the consumption of battery life. In Fowler (2011) and Zhou et al. (2008) semi-Markov process is used to conserve battery life of UE and shows that UE consume 0.5W/Transmission Time Interval (TTI) in active state and 0.011 W/TTI in light sleep and does not consume battery life in deep sleep mode. The total saving of battery life is 0.489 W/TTI. In Polignano, Vinella, Laselva, Wigard, and Sorensens (2011), authors used the semi-persistent and dynamic packet scheduling to check the impact of power saving in LTE. The result shows that semi-persistent is more efficient than the dynamic packet scheduling for power saving because it consumes less PDCCH rather than dynamic packet scheduling. Recursive deduction and Markov model have been used in Tseng et al. (2016) for analysis of power saving using DRX. Mixed short and long DRX cycle is used with Poisson process for the arrival of packets. The result showed that proper choice of parameters can conserve the battery life of UE and reduce delay of the packets. Jin and Qiao (2012) introduced a method for modeling DRX parameters in LTE networks for analysis of power consumption of UE and transmission delay of packets without considering the dynamic conditions of the network. It can affect the QoS of the network. Therefore DRX parameters can further be optimized, and it is still an open issue.

2.2. Scheduling

Scheduling is considered by 3GPP as an important issue in wireless communication due to an exponential growth of technology. The scheduler allocates radio resources among UE so as to fulfil the QoS requirements and this process is known as scheduling. The basic aim of scheduling scheme is to maintain the fairness among UE, packet losses and delay such that all should remain within the satisfaction level. For real-time traffic, the scheduler must guarantee QoS requirement as real-time traffic is delay-sensitive in nature. Channel conditions, throughput history, UE buffer, GBR and Packet delay affects the QoS of networks which become the essential parameters while scheduling. The parameters along with work done on each parameter are presented as follows:

- Channel Quality Indicator (CQI): In wireless communication channel conditions changes frequently. It affects the QoS of networks. Hence, it is necessary to consider this parameter while

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