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Integration Facilitation of Scheduling Algorithms in the Smart Grid Communications over 4G Networks

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***Abstract*—The smart grid is a promising technology of the next-generation electrical systems which involves wireless networks. Such Long Term Evolution (LTE), which has been proposed and developed by the 3rd Generation Partnership Project (3GPP), is expected to be a preferable technology due to its high data rate and low delay. Due to the fact that smart grid requires real-time communications, scheduling mechanism becomes more important since it distributes the available resources to the users taking into account channel status and the Quality of Services (QoS) requirements. However, LTE has not been proposed for smart grid communications so that scheduling algorithms which implemented in LTE network must be evaluated accordingly before integrated in the smart grid communications. This paper evaluates the performance of three scheduling algorithms in the smart grid for both real-time applications and non-real time applications as well. Moreover, the performance is evaluated in terms of delay, throughput and fairness index. In addition, this paper desires to facilitate the integration scheduling process in the smart grid communications.**

***Keywords—smart grid, 4G, LTE, smart applications,* Scheduling, resource allocation**

I. Introduction

The smart grid is a technology which utilizes wireless networks, analog and digital information to optimize the performance of current electricity grid. Furthermore, the smart grid controls and adjusts the behavior between generation and consumption sides which results in low wastage [1]. Fig 1 show the main features added by the smart grid over the current electrical grid:

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Table 1. Samrt Grid Features vs Current Grid

Current Grid	Smart Grid
Electromechanical	Digital
Centralized Generation	Centralized Or Distributed
Hierarchical	Network
Few Sensors	Sensors Throughout
Blind	Self-Monitoring
Manual Restoration	Self-Healing
Manual Check/Test	Remote Check/Test
Limited Control	Pervasive Control
Few Customer Choices	Many Customer Choices

One of the enhancement keys in the smart grid is the integration of communications technology which significantly affects the smart grid performance. It's worth mentioning that the wireless network which integrated in the smart grid should be efficient and reliable [2]. Furthermore, it should meet the real-time communications requirements. Long Term Evolution (LTE), which has been proposed by the 3rd Generation Partnership Project (3GPP), is expected to be a preferable technology due to its high data rate and low latency [3].

The smart grid utilizes real time communications which is controlled and handled by the Radio resource management (RRM). We focus here in this paper on the scheduling mechanism which distributes the available resources among users [4]. It's worth mentioning that LTE is not proposed for smart grid communications and therefore scheduling algorithm performance should be deeply studied and investigated.

The contribution of the paper. This paper investigates the performance of three scheduling algorithms namely Maximum Throughput (MT) and Proportional Fairness (PF) and cooperative game theory (bankruptcy and shapely) with Technique for Order Performance by Similarity to Ideal Solution (TOPSIS) algorithms (BS-TOPSIS) which have shown an acceptable performance in term of throughput, delay and fairness index. Furthermore, the three algorithms are integrated in the smart grid and applied for two smart grid applications (A and B, RT and NRT respectively) which have different data rate and delay requirements. Based on the results, this study facilities the scheduling design process and addresses the weakness of the existing algorithms before integrated in the smart grid.

The rest of paper is organizes as follows. A detail explanation and analysis of the three scheduling algorithms are described in Section 2. Section 3 is dedicated to the simulation parameters. The results are presented and discussed in Section 4. Section 5 concludes the paper.

II. The Scheduling Algorithms

Proportional fairness (PF), the Maximum Throughput and cooperative game theory (bankruptcy and shapely) and Technique for Order Performance by Similarity to Ideal Solution (TOPSIS) (BS-TOPSIS) algorithms are explained below.

A. *Proportional Fairness algorithm*

PF aim at improving the throughput of the overall system regardless the user priority. Moreover, it concerns about non-real time applications (NRT) therefore it is not preferable scheduling algorithm for real time applications (RT) [5]. Its metric doesn't have delay factor as shown in the following equation (1):

$$M_{k,i} = \frac{r_{k,i}}{R_i} \quad (1)$$

where $R_i(t)$ is the average throughput for user k. $r_{k,i}(t)$ is the expected throughput for user k.

B. *Maximum Throughput Algorithm*

Maximum Throughput algorithm (MT) assigns the available resources to the users with maximum achievable throughput. On other words, the users who have the maximum Channel Quality Indicator (CQI) value would be given the priority to be served first. The main drawback with this approach is that the unfair allocation for the users who have poor channel conditions and therefore they will be starved [6]. Equation (2) shows the MT's metric:

$$m_{i,k}^{MT} = d_k^i(t) \quad (2)$$

where $d_k^i(t)$is the maximum achievable throughput.

C. *Game Theory and TOPSIS Based Scheduling Algorithm*

This is a two level scheduling algorithm which is combined of two concepts namely cooperative game theory (bankruptcy and shapely) and Technique for Order Performance by Similarity to Ideal Solution (TOPSIS). However, BS-TOPSIS scheme shows an acceptable performance in terms of throughput, delay and fairness index for both RT and NRT. The first level, bankruptcy algorithm allocates the resources based on class and shapely algorithm distributes the resources among users as a proportion which keeps both RT and NRT applications are considered and served. Second level TOPSIS algorithm allocates the resources based on the class preferences [7].

III. Simulation Scenario

This scenario has been evaluated using LTE simulator. Moreover, the two smart applications (A and B) are RT and NRT respectively. Each application has its own data rate and delay requirements.

Table 2. Data Rate and Delay Requirments

Name	Data Rate(Kbps)	Delay (s)
A	242	0.02
B	440	2

IV. Results and Discussion

The overall system performance is evaluated in terms of throughput, delay and fairness index. As can be clearly seen from Fig. 1 that BS-TOPSIS shows the maximum throughput followed by MT and PF respectively. MT illustrates better throughput than that of PF because it assigns resources to the users who have the best channel conditions.

Both PF and MT algorithms show high delay compared to the other approach since they doesn't concerns about real time applications (RT) where they only concern about the system throughput regardless the user's priority. Whereas BS-TOPSIS takes in account both RT and NRT applications and the user's priority as well. Furthermore, it assigns resources to both RT and NRT applications as a proportion which results in high overall system performance as shown in Fig. 2.

BS-TOPSIS shows the best performance in terms of fairness whereas the other two algorithms show almost the same as in Fig. 3. As has been previously explained that BS-TOPSIS is very fair since it allocates available resources to both RT and NRT applications as percentage which prevents the starvation.

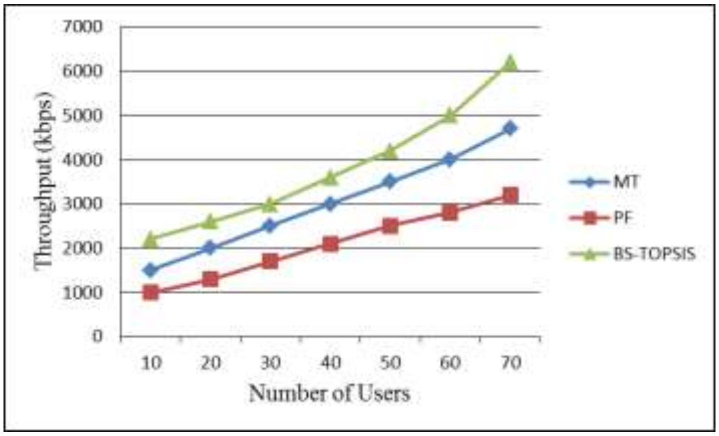

Figure 1. System Throughput

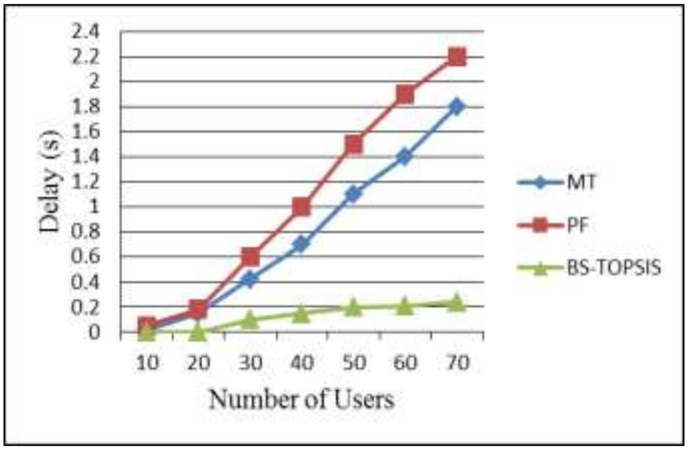

Figure 2. System Delay

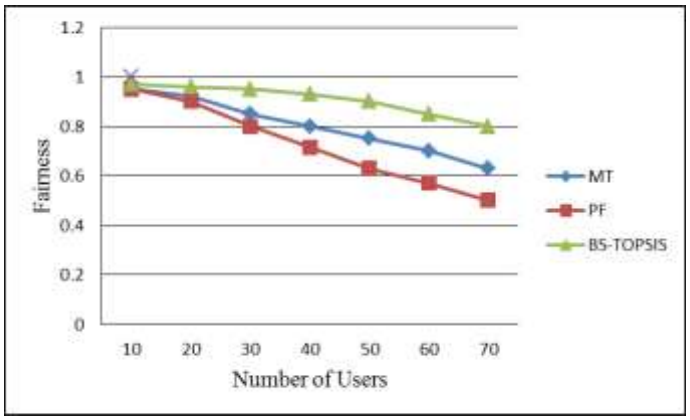

Figure 3. System Fairness

V. Conclusion

This paper has evaluated the performance of three scheduling algorithms namely Maximum Throughput (MT), Proportional Fairness (PF) and cooperative game theory with Technique for Order Performance by Similarity to Ideal Solution (TOPSIS) algorithm (BS-TOPSIS). The evaluation process is based on their performance in two smart grid applications (A and B, RT and NRT respectively). However, BS-TOPSIS has illustrated the best performance in terms of throughput, delay and fairness index. Whereas PF approach has showed the worst performance for the three studied parameters compared to the other two approaches. MT has maintained its performance at the middle of the other two approaches. Moreover, its performance is considered acceptable in term of throughput and fairness index for this specific scenario.

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References

[1] Gungor, Vehbi Cagri, Dilan Sahin, Taskin Kocak, Salih Ergut, Concettina Buccella, Carlo Cecati, and Gerhard P. Hancke. "A survey on smart grid potential applications and communication requirements." Industrial Informatics, IEEE Transactions on 9, no. 1 (2013): 28-42

[2] Yan, Ye, Yi Qian, Hamid Sharif, and David Tipper. "A survey on smart grid communication infrastructures: Motivations, requirements and challenges."Communications Surveys & Tutorials, IEEE 15, no. 1 (2013): 5-20.

[3] Hajjawi, Ayman, Mohammad Nour Hindia, Mahamod Ismail, Kamarul Ariffn Noordin, and Mohamad Dernaika. "Teleoperation Scheduling Algorithm for Smart Grid Communications in LTE Network." In Applied Mechanics and Materials, vol. 666, pp. 340-345. 2014.

[4] Fan, Zhong, Parag Kulkarni, Sedat Gormus, Costas Efthymiou, Georgios Kalogridis, Mahesh Sooriyabandara, Ziming Zhu, Sangarapillai Lambotharan, and Woon Hau Chin. "Smart grid communications: Overview of research challenges, solutions, and standardization activities." Communications Surveys & Tutorials, IEEE 15, no. 1 (2013): 21-38.

[5] Lee, Suk-Bok, Ioannis Pefkianakis, Adam Meyerson, Shugong Xu, and Songwu Lu. "Proportional fair frequency-domain packet scheduling for 3GPP LTE uplink." In INFOCOM 2009, IEEE, pp. 2611-2615. IEEE, 2009.

[6] Capozzi, Francesco, Giuseppe Piro, Luigi Alfredo Grieco, Gennaro Boggia, and Pietro Camarda. "Downlink packet scheduling in lte cellular networks: Key design issues and a survey." Communications Surveys & Tutorials, IEEE 15, no. 2 (2013): 678-700.

[7] Hindia, Mohammad Nour, Ahmed Wasif Reza, and Kamarul Ariffin Noordin. "A Novel Scheduling Algorithm Based on Game Theory and Multi-Criteria Decision Making in LTE network.

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