Original Article

DEVELOPMENT AND MANAGEMENT OF SMART POWER GRID EFFICIENCY WITH 5G GENERATION TECHNOLOGY

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Abstract

Due to the management and deployment of the 5G technology in the smart power grid, there will be some impacts affecting the cost and energy efficiency, especially in the areas of not reliable power grid and not available, in addition, the operators are not experts to use the 5G technology infrastructure. The 5G infrastructure is affected by several factors such as Large Cells, Unmanned Arial Vehicle (UAV), Capital Expenditures CAPEX, and Operating Expenditures OPEX costs. Results obtained show that an off-grid network with 5G can be constructed with good efficiency and low effects on the wide range wireless network connectivity, especially for users living in rural and small areas of low income instead of wire connectivity in addition the application of renewable solar energy sources will let the off-grid operating efficiently in emergencies conditions. With this technology, the cost and time of the power grid network distribution will be optimized and minimized. Meanwhile, the smart power grid management which will be offered by the 5G has more reliability and produce smart adaptive patterns with solar energy.

Keywords— Capital Expenditures, Challenges, energy efficiency, OPEX Expenditures, renewable energy.

Introduction

5G technology can enhance the efficiency and cost compared to 4G. Table 1, shows a traditional 5G urban compared to a 5G rural structure. According to the type of service, people in these places, have good HD video, and better networks. In addition to other required services including emergency services, electronic- environment, and electronic – Teaching (L. Chiaraviglio, N. Blefari-Melazzi, W. Liu, J. A. Gutierrez, J. Van De Beek, R. Birke, L. Chen, F. Idzikowski, D. Kilper, J. P. Monti, et al 2016).While people who live in these places looking for good compared to HD videos because smart adopted devices such as smartphones in these zones are cheaper.Also, users in these zones, are paying monthly subscription fees, like the people living in urban and rural areas. The main impacts that will be discussed in this paper such as the cost, 5G efficiency, analyzing in addition to the efficient management of UAV-based networks.

TABLE 1. 5G Urban Comparison with Rural and small-income Areas

Item	**5G Urban Scenario**	**5G Rural Scenario**	**5g Low-income Scenario**
Service Type	HD Video, HD Streaming, Tactile Internet, IoT	HD Video, Emergency Service, e-Health, e-Learning	Basic Connectivity, Emergency Service, Delay Tolerant, e-Health, e-Learning
Network Constraints	Maximize Bandwidth, Minimize Delay, Coverage	Coverage, Guaranteed Bandwidth	Coverage
Energy Sources	Power Grid	Power Grid, Renewable Sources	Unreliable Power Grid, and/or Renewable Sources
Monthly User Subscription Fees	Pay Per Bandwidth	Same as standard urban users	Low
Business Model	Return on Investment	Subsidized by the government	Subsidized by the government
Required Network Flexibility	High	High	High
User Mobility	Pedestrian, Vehicular, High Speed Vehicular	Pedestrian, Vehicular	Pedestrian, Low Speed Vehicular

I. Architecture of an Efficient 5G Off-Grid

Table 2, shows the main pillars of the efficient 5G Off-Grid Architecture.

TABLE 2 Main Pillars of the Efficient 5G Off-Grid Architecture

Pilar	**Description**
Converged Solution	The networking and computing sources are jointly managed by an orchestrator. The physical devices of the access network are managed in conjunction with the metro and core ones.
Virtualization of Network Components	Virtualization of network and computing components by means of virtual functions that are controlled by a centralized orchestrator. Efficient Management of the virtual resources on a set of physical devices.

Exploitation of Commodity Hardware	Exploitation of general purpose HW to host the virtual functions in order to reduce the CAPEX and OPEX costs.
Solar-Powered Energy-Efficient Devices	Massive exploitation of solar panels to power the physical devices. Exploitation of backup batteries to provide electricity when the energy of sun is not available.
Unmanned Aerial Vehicles and Ultra-Large Cells	Exploitation of the UAVs to carry radio network elements. Exploitation of LC mounted at ground to realize massive antenna array covering ultra-large sizes.

The following technologies are adopted in this work: i) UAVs loading the elements of radio network, and Base Stations BSs and ii) LCs installed at the site, applying massive array antenna vast portions of territory (M. Mozaffari, W. Saad, M. Bennis, and M. Debbah 2015).

Figure 1, explains a scenario of the power resources supplying 5G equipment host site and there are energy sources: i) the grid power, ii) the PV panels, and iii) the batteries for backup (M. Eriksson and J. van de Beek 2015).

Figure. 2, shows a backup old diesel generator in addition to the power supply through a diesel generator

FIGURE 1: Power supply for a 5G site with solar panels.

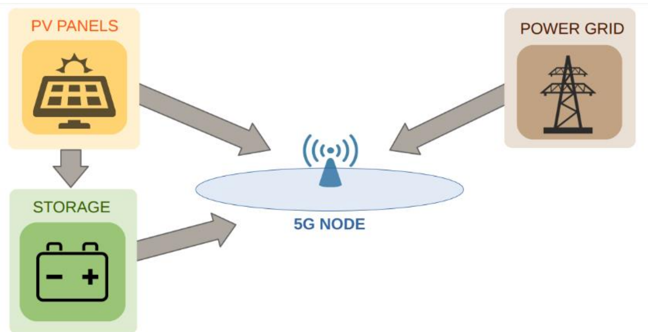


Figure 3 shows the block diagram of the deployment solution of Large Cells and UAV-based. In the LC- (Fig. 3. (a)) the 5G site hosts Commodity HardWare (CHW) and Dedicated Hardware (DHW) in addition there is a physical splitting between them. In this method, the flight time of UAV will be positively affected (L. Chiaraviglio, W. Liu, J. A. Gutierrez, and N. Blefari-Melazzi 2017).

FIGURE 2: Power supply for a 5G site with solar panels and diesel generator in case the power grid is not available.

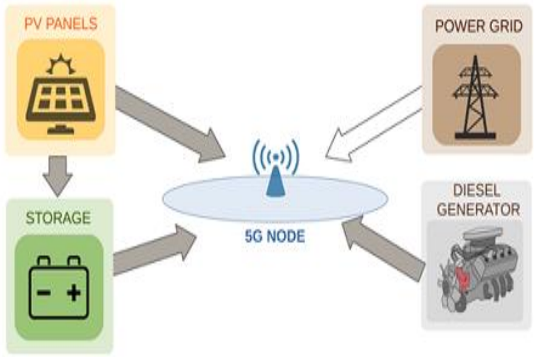
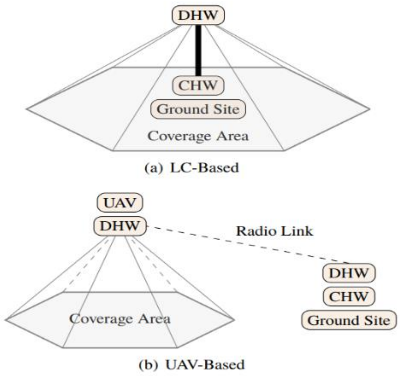


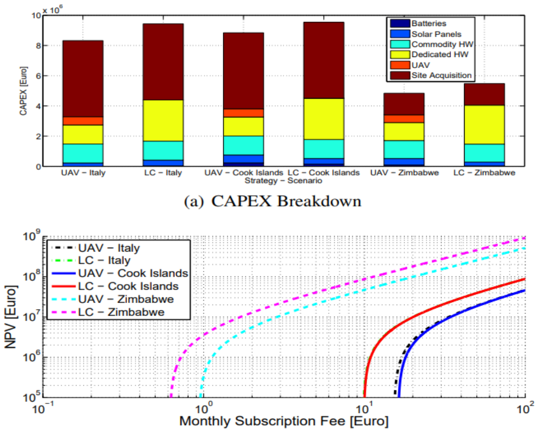
FIGURE 3: 5G deployment options under consideration



I. Cost Analysis

Three sites in three countries are discussed in this paper, namely: i) Italy scenario, ii) Cook Islands scenario, and iii) Zimbabwe scenario (L. Chiaraviglio, N. Blefari-Melazzi, W. Liu, J. A. Gutiérrez, J. van de Beek, R. Birke, L. Chen, F. Idzikowski, D. Kilper, P. Monti, et al 2017). For each scenario, the LC-based and the UAV-based solutions are considered. Figure 4(a) discussed the CAPital incomes and CAPEX Overall, the total CAPEX costs are in the order of millions, in Zimbabwe low expensive for employees. Figure 4(b) explains the results of Net Present Value (NPV), an economic indicator including CAPEX, OPEX, and revenues from users. In particular, when the NPV, where the application of 5G is affordable for the worker. It can be noted that, monthly subscription fees, in the order of 1 [EUR] for the Zimbabwe and 10 [EUR] for the Cook Island and Italian (L. Chiaraviglio, N. Blefari-Melazzi, W. Liu, J. A. Gutiérrez, J. van de Beek, R. Birke, L. Chen, F. Idzikowski, D. Kilper, P. Monti, et al 2017).

FIGURE 4: Net Present Value (NPV), CAPEX breakdown by inserting UAV and Large Cells.



(a) CAPEX Breakdown

(b) NPV, 5% Discount Rate

II. Analysis of Cost Minimization

Table 3 summarizes the number of batteries and solar panels applied at each site, shows that each site manages UAVs. Figure 5 shows the total costs for the optimized UAV, While figure 6, illustrates the applied sites and there, the BS stations are loaded by the UAV, then different sites to be covered by the UAV. Figure 7 mentions level of the batteries zone of 5 G (L. Chiaraviglio, L. Amorosi, N. Blefari-Melazzi, P. Dell'Olmo, C. Natalino, and P. Monti,2018).

FIGURE 5: Breakdown of the equipment costs for the UAV-based.

Metric	Site ID		
	9	10	15
Batteries	21	15	15
Solar Panels	10	8	7

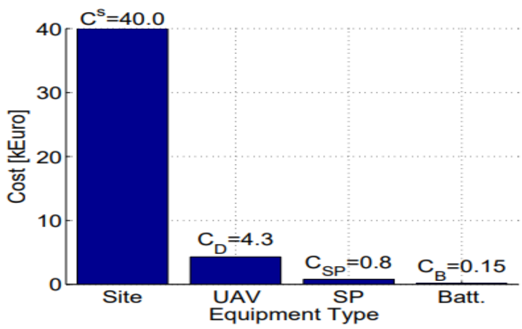


FIGURE 6: Installed sites and fiber links for the UAV-based solution .

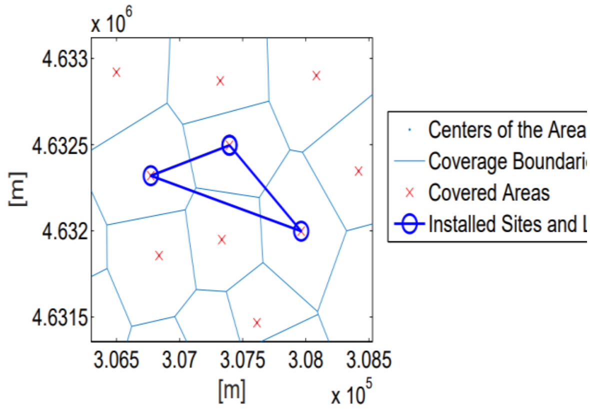
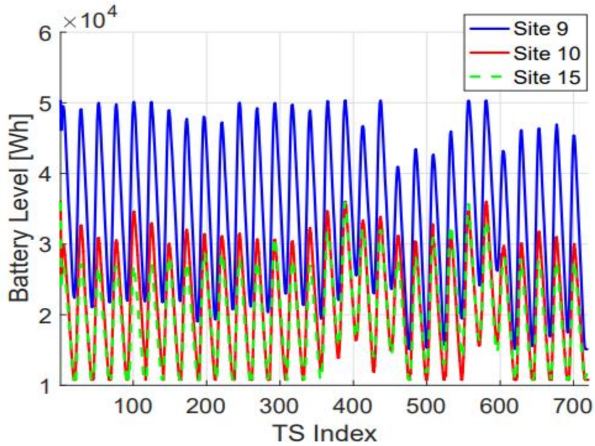


FIGURE 7: Temporal variation of the battery levels.



III. Design of Efficient Management

Figure 8, shows the mission of UAV in four parts, namely: i) recharging in a ground site, ii) moving from the ground site to an area, iii) covering an area, and iv) moving back to the ground site (L. Amorosi, L. Chiaraviglio, F. D'Andreagiovanni, and N. Blefari-Melazzi,2018). To limit the amount of energy requested to the ground site during the recharging operation, it is of mandatory importance to reduce the energy consumed when moving the UAV, therefore, efficient management of the UAVs is pursued in this step.

FIGURE 8: TS and link.

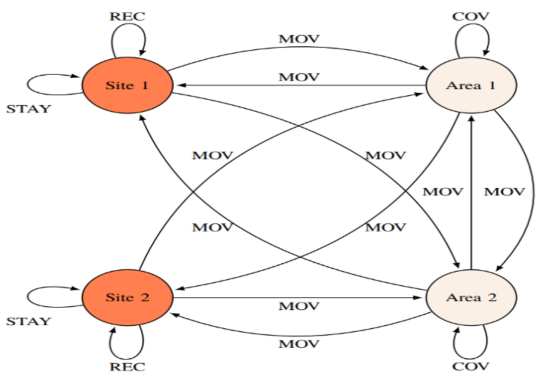


Figure 9 shows the links between two sites and two areas while, Figure 10, mentions a multi-period graph composed of one source node, different nodes, and one sink node. Then a flow variable to each UAV and each link is associated. By properly setting the flow variables over the multi-period graph, the energy consumption and the trajectory of the UAVs can be controlled. The following energy-efficient (EE) strategy over the multi-period graph. Given: a set of areas to be covered, a set of UAVs.

FIGURE 9: Multi-Period Graph.

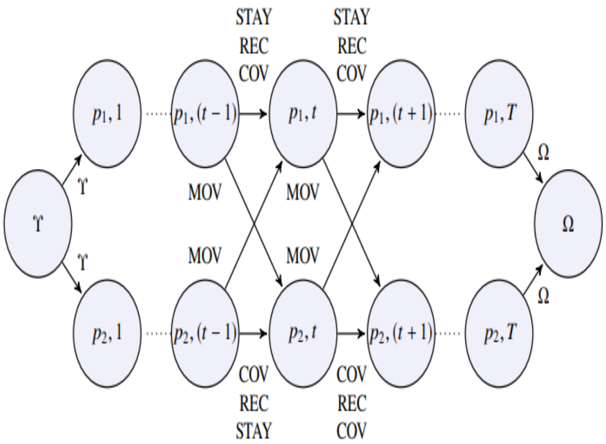


TABLE 4 EE and MC comparison

Metric	MC	EE		
		TL=2 [h]	TL=24 [h]	TL=48 [h]
Energy due to moving operations [Wh]	86982.4	31150.6	29115.7	23858.8
Problem gap [%]	$< 10^{-6}$	54.6	50.2	38.1

The energy-efficient (EE) strategy based on the multi-period graph and compare it against a maximum coverage solution (MC) is applied, which does not take into account the energy consumed by the UAV. Table 4 shows the two strategies comparison.

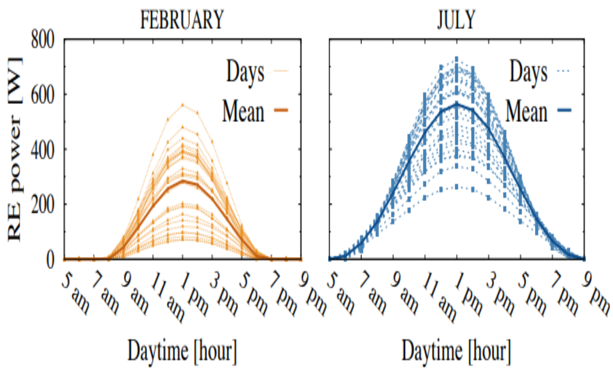
By the EE strategy good results were obtained in this development, First, the energy is decreased by the EE strategy. Second, the energy due to moving tends to decrease the computation time. Third, the gap is very low.

Renewable Energy Sources

The cellular network demand, and services are increasing rapidly in different geographical areas. The solution offered by operators depends on diesel power generators' usage. In these scenarios, the use of Renewable Energy Sources RES has become an extremely attractive option (V. Chamola and B. Sikdar 2016). Refer to figure 2, which shows that power for a BS, with some battery units can be stored, by backup generator.

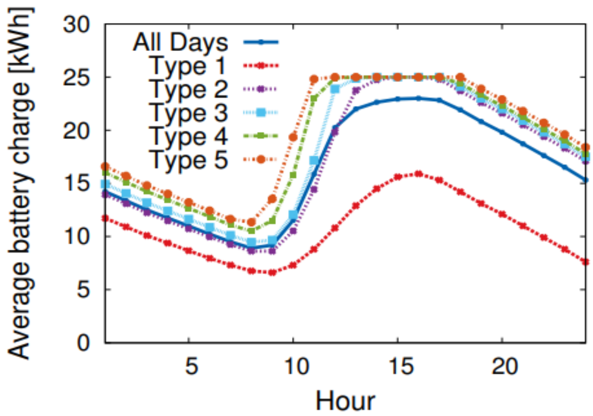
Figure 10 explains the energy production profiles daily of a solar panel of 1 kWp in Torino (D. Renga and M. Meo,2016). The plot on the left belongs to the February days, and those at the right July; these values are resulted with the tool PVWatts and obtained from real location-based data and considering the Typical Meteorological Year (A. P. Dobos, PVWatts Version 5 Manual,2018).

FIGURE 10: Production of Renewable Energy per 1 kW Per Day .



It can be noted the following results; First, there are some night hours, no production at all Second, there are various seasons. Finally, within the same season, energy production levels on different days are noticed in Figure. 11. A winter period in the city of Torino, a power supply system of 30 kWp, and a battery with 25 kWh capacity are concluded (A. C. da Silva, D. Renga, M. Meo, and M. A. Marsan,2018). A few consecutive days of type 1 will hence produce some BS power outage unless some backup supply is available.

FIGURE 11: Battery Charge Hourly



To obtain good results, a smart considerations of energy production variability effects are required. Power demand in Third G and Forth G cellular systems, are low load. The flexibility of 5G technology brings modern facilities. The opportunity to localize resources in a good dynamic way, and distribute the virtualized network functions among the nodes of the network, translates into the possibility to also make the electricity demand more flexible and more suited to be powered with RES.

Conclusions

In this paper, the efficiency and off-grid operation of a 5G network by using UAVs and large cells are applied in addition to renewable energy sources. The total costs for these new solutions are estimated to obtain good profits for people in rural and low-income areas. The other achievement is the minimization of the Capital costs, when using a UAV-based solution which limits the number of ground sites by 5G in addition to increase the areas coverage through UAVs. The results achievements for the operator, when the subscription fee is in the order of 10 [EUR] monthly for the rural areas and 1 [EUR] for the areas of low-income. Also, it is concluded that the acquisition site costs increased, such as the PV solar, the UAVs, and the batteries. Finally, designing a road map of graphs of multi-period to model the UAV's trajectories in addition to the actions they needed over the required time. It is concluded that when using the UAVs, the energy spent for moving the UAVs is decreased and modifies the coverage of the sites, also there are some drawbacks by the UAV and the radio channel when the realization of the Large Cells and the UAV when the energy levels are modeled assuming UAV heights to fly. In addition to modifying the nodes of the network by applying renewable energy sources. Renewable sources are more reliable and highly variable, both on the time scale of days as well as on a seasonal basis., For future work, it is suggested to apply 5G small cells instead of large cells which will decrease the overall capital and time.

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