

## ENHANCEMENT CAPACITY OF LTE CELLULAR NETWORK USING TVWS CONSIDERING MINA CITY

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### Abstract

Through there is an increasing demand for mobile broadband, especially in densely populated areas where there is are lack of cellular spectrum resources, to take more efficient approaches and to take advantage of unused white-spaces are essential. Long Term Evolution (LTE) continues to evolve with higher data rates and improved services, even for the cell edge users as the major aim. In this paper, we present a solution to carry out performance of the fraction frequency reuse (FFR) scheme in an LTE cellular network using TV white space and show that the FFR scheme improves the spectral effectiveness by allowing one out-of-cell interference. Power control system have been used in this simulation in order to enhance the capacity of the cell considering possible network implementation in the densely populated City of Tents Mina.

**Keywords:** TV White-space, LTE, FFR, SINR, CCI, Power Control.

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### 1. Introduction

The next generation of cellular data networks and beyond will face an exponential enlargement of wireless data traffic producing from the proliferation in multimedia applications applying on smart phones, tablets and other smart devices. Available 4G (licensed) spectrum represented by Long Term Evolution (LTE) will obviously be insufficient to meet users demand, this huge demand leading to cellular operators searching for other mechanisms to achieving operational efficiency that enhance network capacity especially in densely populated areas. The ultimate objective of this work is to come up with the enhanced cellular network planning guideline with respect to Mina city. Mina (also known as the Tent City) is a small city located in the province of Makkah, western Saudi Arabia. There are more than 100,000 air-conditioned tents in Mina providing temporary accommodation to 3 million pilgrims of Hajj (annual event where millions of Muslims from around the world make the journey of life) (<http://www.amusingplanet.com>).

One traditional approach in populated wireless areas has been the deployment of more base stations (BSs), but this increases complexity and cost (Lee & Kang, 2000). Another solution is to employ advanced physical layer technologies to increase the spectral efficiency, even though this solution is still not sufficient in today's massive demand. Study in (Khandekar et al., 2010) investigates how the performance of physical layer is oncoming its theoretical limits. Al-Haddad, Aldabbagh and Dimitriou (2015a) have proposed an algorithm using clustering based on k-mean clustering method without using any additional infrastructure and without considering co-channel interference. Tabrizi, Farhadi and Cioffi (2013a) proposes node which refers to a mobile device that can connect with base station (BS) directly then the other nodes which relay on it using cellular-based TVWS in their algorithm. Their configuration allows to use both TVWS and another cellular band by just changing its frequency of operation when required Study in Tabrizi, Farhadi and Cioffi (2013b) proposed an algorithm that forms hotspot-slave configuration and tethering over TV white-space with cellular based access method in a dense populated wireless areas has been investigated. In Tabrizi et al. (2014) iCaRA algorithm has been proposed to meet user demands in dense areas by utilizing unlicensed white-spaces (WS) band for data offload

with re-using resources between clusters using hotspot-slave formation. Aldabbagh et al. (2015) proposed a new method called QoS -Aware Tethering in a Heterogeneous Wireless Network (QTHN) using LTE and TV white-spaces to develop QoS for Best Effort (BE) users and Constant Bit Rate (CBR). In Khalifah, Akkari and Aldabbagh (2014) three major challenges which are the mobility management, interference and offloading has been discussed, in addition, comparison between the access types of femtocells has been studied in case of dense wireless areas. In paper Akkari et al. (2014) a new approach of dynamic clustering has been proposed taking into account the conditions of the cells. Also, the authors studied the performance of the proposed protocol by modeling different networks scenarios and computing the essential number of handovers as a role of user mobility, availability of network resources and data rate requirements for nodes arranged into given cluster (Akkari et al., 2013). In Aldabbagh et al. (2015) the study discussed how dynamically configured new clusters using proposed Distributed Dynamic Load Balancing (DDLb) cellular-based device which by simply switching its frequency can operate on both LTE and TVWS when necessary to solve the congestion problems in a HetNet. Paper in Al-Haddad, Aldabbagh and Dimitriou (2015b) proposed algorithm takes benefit of the available white-spaces band to offload traffic and exploits the clustered configuration to reuse frequency amongst them. Also, it takes advantage of K- mean algorithm to utilize the close proximity of the nodes to generate clusters, in which an elected node serves as a hotspot for others. The simulation results show that this proposed algorithm can considerably decrease both of the total number of restrict users and the required transmission power for communication.

The rest of this paper is organized as follows. The system model is presented in section II. In section III, we illustrate the proposed strategy in detail. In section IV, we show the simulation results of the proposed strategy through the simulations. Finally, some conclusions are given in section V.

## 2. System Model

This paper considers a similar environment as in the densely populated area in Mina city at Hajj season in Saudi Arabia. Mina city of tents as it is called is an area of approximately 2.5 million square meters and accommodate for 2.6 million pilgrims ([http://www.kapl-hajj.org/mina\\_tents\\_development.php](http://www.kapl-hajj.org/mina_tents_development.php)). This area divided into blocks and each one contains around 6 to 10 tents (clusters). It is proposes a concept in which a mobile node (hotspot) act as master mobile device in each tent (cluster) that can connect with base station (BS) directly and then relay the downlink and uplink data rate with its own data rate by aggregating both the signal to other nodes (slaves) mostly 10 users per tent, when communicating with the base station. In addition, slaves refer to mobile devices that communicate with BS through the hotspot. This configuration is depicted in Figure 1.

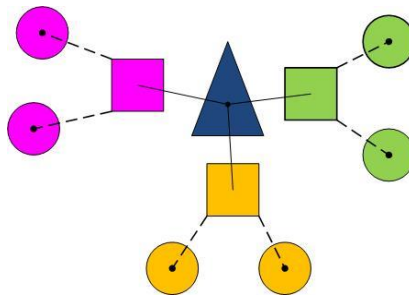


Figure 1 Clusters configuration in a macro cell

Assume a hexagonal macro-cell in which the radius equals 100m with 8 tents (clusters). Each tent contains of 10 users up to 30, according to the size of tent (<http://www.rferl.org/content/article/1073721.html>). Each standard tent measures 8 x 8 meters; in addition, there are smaller (8 x 6 meters) and larger (8 x 12) tents ([http://www.kapl-hajj.org/mina\\_tents\\_development.php](http://www.kapl-hajj.org/mina_tents_development.php); <http://www.rferl.org/content/article/1073721.html>; <http://www.amusingplanet.com/2014/08/mina-city-of-tents.html>).

There are  $U_d$  active number of direct users in macro cell which randomly and uniformly distributed within the cells and need to communicate with their own base station (BS). Each direct node  $u_1 \in U_d = \{1, 2, \dots, U_d\}$ . There are  $U_c$  number of users in 8 tents (clusters) with 10 users inside the macro cell, so  $u_c = \{1, 2, \dots, U_c\}$  can act either as a hotspot (HS) or slaves users (S) and this function can be changed with regards to the cluster conditions. Total number of users in the cell  $U = U_d \cup U_c$  and  $U_d \cap U_c = HS$ . Such that inside each cluster  $S \cup HS = U_c$  and  $S \cap HS = \emptyset$ . In a Direct Mode (DM) the hotspots communicate directly to the BS and in a Relay Mode (RM) the slaves connect to the BS through hotspot as depicted in Figure 1.

This configuration produces non-overlapping two-layer transmission scheme in the cell, where the first layer is the BS-hotspot links which provides the required data to the hotspots in LTE and the second layer is the hotspot-slave link in TVWS. Hence, the first layer represents as wireless network backhaul for all the hotspots and slaves. In the first layer, there are  $L$  number of licensed band (LTE) available channels that can be used by the nodes which are directly connected to the base station (BS). On the other hand, there are TV white space channels that can be used in the second layer connections.

### 3. Power Control

To increase system capacity, coverage, service quality and reduce power consumption, we use power control in uplink signals from mobile station to base station. Power control refers to setting output power levels of transmitters, it typically aims to reduce the interference, while maximizing the received power of desired signals (Simonsson & Furuskar, 2008).

#### 1) Uplink Power Control in LTE

Due to the LTE uplink which is orthogonal, it allows multiplexing of terminals with different received uplink power within the same cell, there is no interference between users in the same cell, in the best case, but at least there is only interference between cells. The amount of interference generated to neighbor cells depends on other things such as the mobile-terminal location when terminals close to neighbor cells produce more interference than terminals far away hence transmit with a higher power than terminals near the cell. Other reason the path-gain from the terminal to these cells.

The LTE uplink power control is based on both signal strength measurements done by the terminal itself (open-loop power control) as well as measurements by the base station, used to generate transmit power control commands that are subsequently fed back to the terminals as part of the downlink control signaling (closed-loop power control) (Simonsson & Furuskar, 2008).

In this simulation, we used closed-loop power control and calculated transmission power as follow:

$$P_{tx} = N + PL + SINR_t \quad (1)$$

Where:

$P_{tx}$ : Transmit power

$N$ : Noise

$PL$ : estimated pathloss

$SINR_t$ : Signal interference to noise threshold

And using this equation for SINR calculating.

$$SINR_i = \frac{\frac{P_{tx,i}}{L_{ij}}}{\sum_{\substack{k=1 \\ k \neq i}}^n \frac{P_{tx,k}}{L_{kj}} + N} \quad (2)$$

Where  $P_{tx,i}$  is the transmit power of the  $i$  user.  $L_i$  is the user  $i$  path-loss,  $j$  hotspot ID,  $L_{ji}$  the path loss between each hotspot  $j$  and each user  $i$ .  $N$  is the total noise ratio,  $K$  is the number of users currently being served by that BS.  $N$  is the noise power In the equation (2) the denominator is the term which corresponds to the co-channel interference from the  $n$  users in neighboring clusters using the same channel. Calculating throughput of each user has been calculated according to equation (3) as follows:

$$Throughput_i = BW \cdot \log_2 (1 + SINR_i), \quad i = 1, 2, 3 \quad (3)$$

## 2) Downlink No power control in LTE

In the downlink, there is a simple and efficient strategy for power control, which used in most recently systems, is to transmit with a fixed transmission power. Usually, the maximum transmission power of base station is used. Difference in interference levels and channel conditions are adapted to by means of scheduling and link adaptation rather than with power control (Simonsson & Furuskar, 2008). No Power Control (No PC) assumed by using Fixed transmission power, the UE power is set to  $P = P_{max}$ , where  $P_{max}$  is the maximum UE power. Used as a reference case. This can be applied in LTE by setting  $\alpha = 0$  and  $P_{tx} = P_{max}$ .

## 4. Fractional Frequency Reuse (EFR)

Orthogonal frequency division multiple access (OFDMA) is a promising multiple access technique has been supported by Long Term Evolution (LTE) system where frequency reuse of one is used. However, due to serious Co-channel Interference (CCI) in frequency reuse, the case of cell edge users appears they could suffer problems in their communication quality (Ali-Yahiya, 2011).

In order to relieve the cell edge interference problem interference, using Fractional Frequency Reuse (FFR) has lately been proposed for orthogonal frequency division multiple access (OFDMA) networks, which are presently being considered in LTE-A and WiMAX IEEE 802.16m standardization processes (Ghaffar & Knopp, 2010). FFR (Kwan & Leung, 2010) is an interference management technique that divide the given bandwidth into an inner and an outer part with different frequency reuse factors. It allocates the inner part to the near users which close to the Base station (BS) in terms of path loss with reduced power applying a frequency reuse factor of one e.g. the inner part is totally reused by all BSs. For users closer to the cell edge (far users), a fraction of the outer part of bandwidth is dedicated with the frequency reuse factor greater than one. Figure 2 shows the traditional Fractional Frequency Reuse (FFR) for LTE. F1,

F2 and F3 represent different sets of sub-channels in the same frequency channel. With this configuration, the full load frequency reuse one is maintained for inner cell UEs to maximize spectral efficiency, and fractional frequency reuse is implemented for outer ring UEs to assure edge-UE connection quality and throughput (Ali-Yahiya, 2011). In this section, FFR techniques have been typically been applied through simulations using a hexagonal grid for the base station locations.

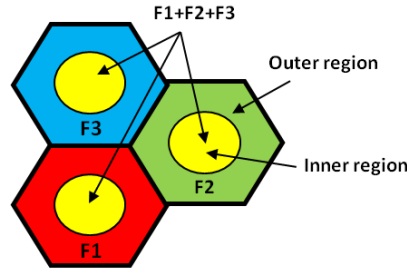


Figure 2: FFR in LTE. Frequency reuse factor for cell edge users is 3

## 5. Simulation Results

We simulate one hexagonal macro cell with radius 100m and 100 users. Table 1 below shows parameters of simulation.

Table 1 simulation parameters

Parameter	Value
Cellular layout	Hexagonal grid
Antenna	Omni directional
Simulation Scenario	Dense urban
Macro-cell Radius	100m
radius of each cluster	8 m
Fixed TX power for user	24 dBm
Fixed TX power for BS	44dBm
LTE Bandwidth (MHz)	20
SINR threshold in dB	10 dB
number of clusters	8
Path Loss Exponent	4
number of users within a cluster	10
number of tvws channel in each cluster	10
No. of LTE RBs	100
No. of users within a Macro cell	20
Total No. of Users	100
Noise Power	-120 dBm
UE distribution	Randomly uniformaly

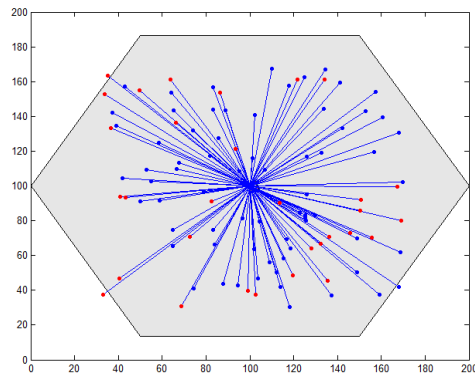


Figure 3: macro cell with 100 users

Figure 3 shows one macro with 100 users blue nodes represent connected nodes and the red nodes represent the blocked users. Figure 4 shows the transmission power in uplink case.

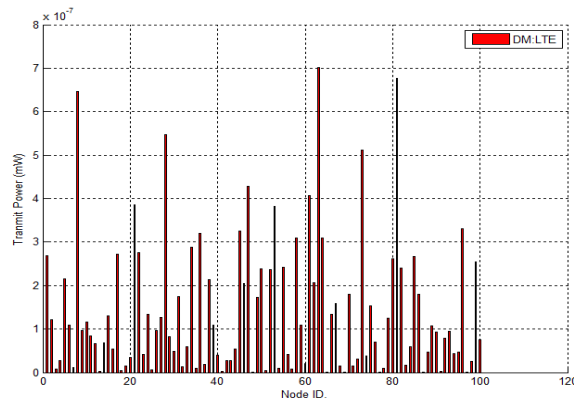


Figure 4: uplink transmission power in DM

Figure 5 shows the macro cell after adding 8 clusters

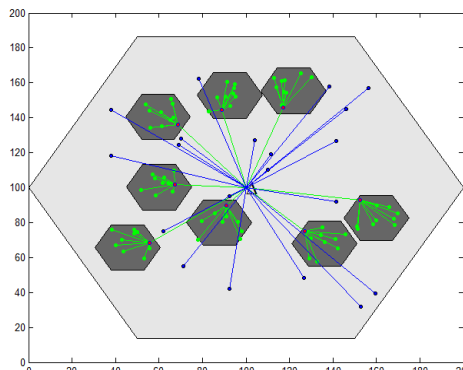


Figure 5: macro cell after clustering

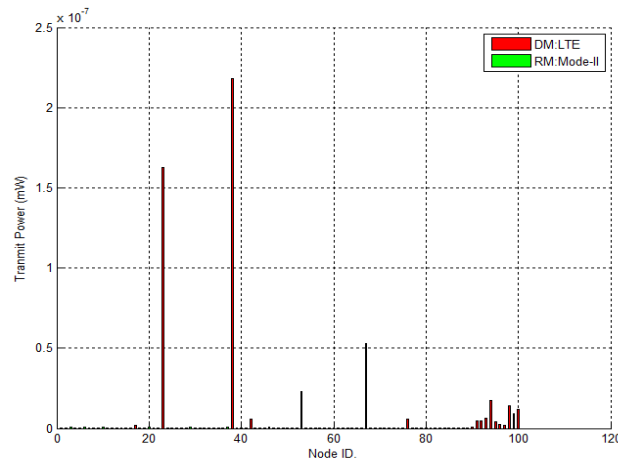


Figure 6: Uplink transmission power DM vs. RM

Figure 6 shows clearly how relay mode reduce 49% of transition power per each user. Figure 7 shows comparison between throughput average for macro users , clusters users and Direct user which use only LTE band . Figure 8 combines the Macro and Cluster results to be between Direct mode (No clusters) and Relay mode (clusters). The results show how the Relay mode increase the throughput 104% than Direct mode.

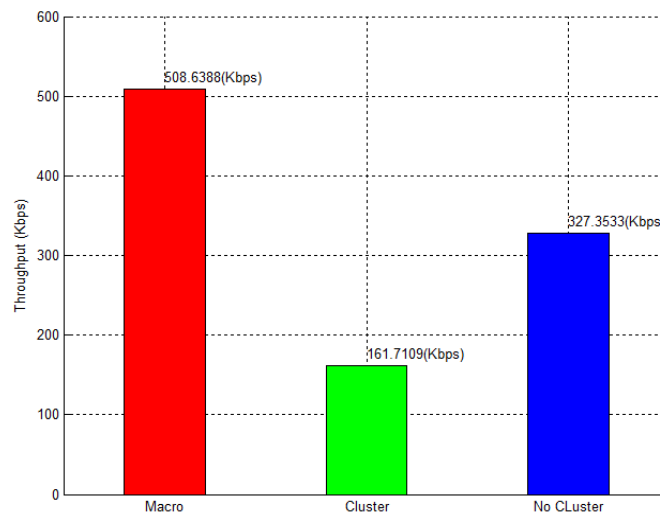


Figure 7: Throughput average between macro, clusters and no clusters

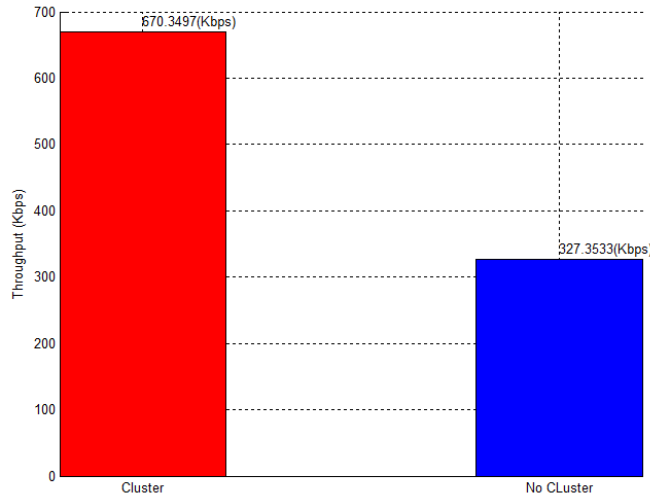


Figure 8 Throughput Cluster Vs. No Cluster

Blocked Rate = 0.000000, Outage Rate = 80.000000  
 LTE Average throughput per user for Uplink = 622.697691  
 TVWS Average throughput per user for Uplink = 622.697691  
 LTE Average throughput per user for Downlink = 161.710948  
 TVWS Average throughput per user for Downlink = 649.218625  
 Total DM transmit Power in (mW) = 5.493980e-07  
 Total RM transmit Power in (mW) = 1.307511e-08

-----FOR UPLINK POWER CONTROL-----						
-----MACRO USERS-----						
ID	CCI	Tx Power (mW)	SINR (dB)	Throughput (Kbps)	RB ID	
1 (HS)	0.000000e+00	5.267684e-08	10.000000	622.697691	34	
16 (HS)	0.000000e+00	1.154490e-08	10.000000	622.697691	1	
30 (HS)	0.000000e+00	7.900461e-08	10.000000	622.697691	35	
36 (HS)	0.000000e+00	8.777989e-08	10.000000	622.697691	36	
45 (HS)	0.000000e+00	3.496868e-10	10.000000	622.697691	37	
59 (HS)	0.000000e+00	5.835727e-08	10.000000	622.697691	2	
61 (HS)	0.000000e+00	4.466060e-08	10.000000	622.697691	38	
75 (HS)	0.000000e+00	1.832291e-08	10.000000	622.697691	39	
81	0.000000e+00	5.267684e-08	10.000000	622.697691	40	
82	0.000000e+00	7.326292e-08	10.000000	622.697691	41	
83	0.000000e+00	1.192407e-07	10.000000	622.697691	42	
84	0.000000e+00	1.131992e-07	10.000000	622.697691	43	
85	0.000000e+00	1.421478e-07	10.000000	622.697691	44	
86	0.000000e+00	9.747781e-08	10.000000	622.697691	45	
87	0.000000e+00	1.930981e-07	10.000000	622.697691	46	
88	0.000000e+00	1.547085e-07	10.000000	622.697691	47	
89	0.000000e+00	7.532821e-08	10.000000	622.697691	48	
90	0.000000e+00	7.463166e-08	10.000000	622.697691	49	
91	0.000000e+00	3.217372e-08	10.000000	622.697691	50	
92	0.000000e+00	2.135799e-08	10.000000	622.697691	51	
93	0.000000e+00	1.281407e-08	10.000000	622.697691	52	
94	0.000000e+00	5.398206e-08	10.000000	622.697691	53	
95	0.000000e+00	1.428953e-08	10.000000	622.697691	54	
96	0.000000e+00	1.156490e-08	10.000000	622.697691	55	
97	0.000000e+00	3.619205e-08	10.000000	622.697691	56	
98	0.000000e+00	2.994284e-08	10.000000	622.697691	57	

Figure 9: screen shot of Macro users info.



## Conclusion

With this extraordinary expansion of mobile technology, the demand for ubiquitous access to wireless data anywhere and at any time become more necessary. This paper considers Mina city of tents with huge populated area in the world and investigates on clustering users into small cells represent tents inside the macro cells. Results show how throughput increase and transmission power decrease by using Relay mode approach than Direct mode approach.

## References

- i. Akkari, N., Aldabbagh, G., Nahas, M., Bawazeer, B., Cioffi, J. & Tabrizi, H., 2013. Coordinated Tethering Over Cellular Networks: Handover Scenarios and Signaling. In *Personal Indoor and Mobile Radio Communications (PIMRC), IEEE 24th International Symposium*, pp. 2170-2174.
- ii. Akkari, N., Aldabbagh, G., Nahas, M. & Cioffi, J., 2014. Dynamic Clustering Protocol for Coordinated Tethering Over Cellular Networks. *Journal of Network and Computer Applications*, 42, pp. 92-101.
- iii. Aldabbagh, G., Bakhsh, S. T., Akkari, N., Tahir, S., Khan, S. & Cioffi, J., 2015. Distributed Dynamic Load Balancing in A Heterogeneous Network Using LTE and TV White Spaces. *Wireless Networks*, pp. 1-12.
- iv. Aldabbagh, G., Bakhsh, S. T., Akkari, N., Tahir, S., Tabrizi, H. & Cioffi, J., 2015. QoS-Aware Tethering in a Heterogeneous Wireless Network using LTE and TV White Spaces. *Computer Networks*, 81, pp. 136-146.
- v. Al-Haddad, U., Aldabbagh, G. & Dimitriou, N., 2015a. Clustering over TV White Space in Dense Wireless Areas: Dynamic Hotspot Selection and Resource Allocation. *MITTEILUNGEN KLOSTERNEUBURG*, p. 12.
- vi. Al-Haddad, U., Aldabbagh, G. & Dimitriou, N., 2015b. Coordinated Cognitive Tethering over TV White-Spaces Considering Co-Channel interference in Dense Wireless Areas. In *International Conference on Computational Science and Computational Intelligence (CSCI'15)*, Las Vegas, Nevada, USA, p. 6.
- vii. Ali-Yahiya, T., 2011. *Understanding LTE and its Performance*. Springer Science & Business Media.
- viii. Ghaffar, R. & Knopp, R., 2010. Fractional Frequency Reuse and Interference Suppression for OFDMA Networks. In *Modeling and Optimization in Mobile, Ad Hoc and Wireless Networks (WiOpt), 2010 Proceedings of the 8th International Symposium*, pp. 273-277.
- ix. Khalifah, A., Akkari, N. & Aldabbagh, G., 2014. Dense Areas Femtocell Deployment: Access Types and Challenges. In *e-Technologies and Networks for Development (ICeND), 2014 Third International Conference*, pp. 64-69.
- x. Khandekar, A., Bhushan, N., Tingfang, J. & Vanghi, V., 2010. LTE-advanced: Heterogeneous Networks. In *Wireless Conference (EW), European*, pp. 978-982.
- xi. Kwan, R. & Leung, C., 2010. A Survey of Scheduling and Interference Mitigation in LTE. *Journal of Electrical and Computer Engineering*, p. 1.
- xii. Lee, C. Y. & Kang, H. G., 2000. Cell Planning with Capacity Expansion in Mobile Communications: A Tabu Search Approach. *Vehicular Technology, IEEE Transactions*, 49, pp. 1678-1691.

- xiii. Simonsson, A. & Furuskar, A., 2008. Uplink Power Control in LTE-Overview and Performance, Subtitle: Principles and Benefits of Utilizing Rather than Compensating for SINR Variations. In *Vehicular Technology Conference, 2008. VTC 2008-Fall. IEEE 68th*, pp. 1-5.
- xiv. Tabrizi, H., Farhadi, G. & Cioffi, J. M., 2013a. Tethering Over TV White-space: Dynamic Hotspot Selection and Resource Allocation. In *Vehicular Technology Conference (VTC Fall), IEEE 78th*, pp. 1-6.
- xv. Tabrizi, H., Farhadi, G. & Cioffi, J. M., 2013b. CaSRA: An Algorithm for Cognitive Tethering in Dense Wireless Areas. In *Global Communications Conference (GLOBECOM), IEEE*, pp. 3855-3860.
- xvi. Tabrizi, H., Farhadi, G., Cioffi, J. & Aldabagh, G., 2014. *Coordinated Tethering over White-Spaces*.  
Other Resources:
- xvii. <http://www.amusingplanet.com/2014/08/mina-city-of-tents.html>
- xviii. [http://www.kapl-hajj.org/mina\\_tents\\_development.php](http://www.kapl-hajj.org/mina_tents_development.php)
- xix. <http://www.rferl.org/content/article/1073721.html>
- xx. <http://www.amusingplanet.com/2014/08/mina-city-of-tents.html>

