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A Unified Call-to-Prayer Framework in Muslim World

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ABSTRACT

In many Muslim countries there are many sounds that are fired at nearly the same time via loudspeakers. This sound is a call-to-prayer (Azan). Azan is fired from the so-called mosques in many countries where, theses mosques are still using its own timing to trigger such call and its own amplifier gain regardless of other mosques in the region. This results in an out of sync call-to-prayer firing and a very noisy and distracting mix of sounds in many places at the same region. In this paper, a unified call-to-prayer framework is proposed that sheds light on these issues and gives solution directions for the above mentioned issues in the currently used systems.

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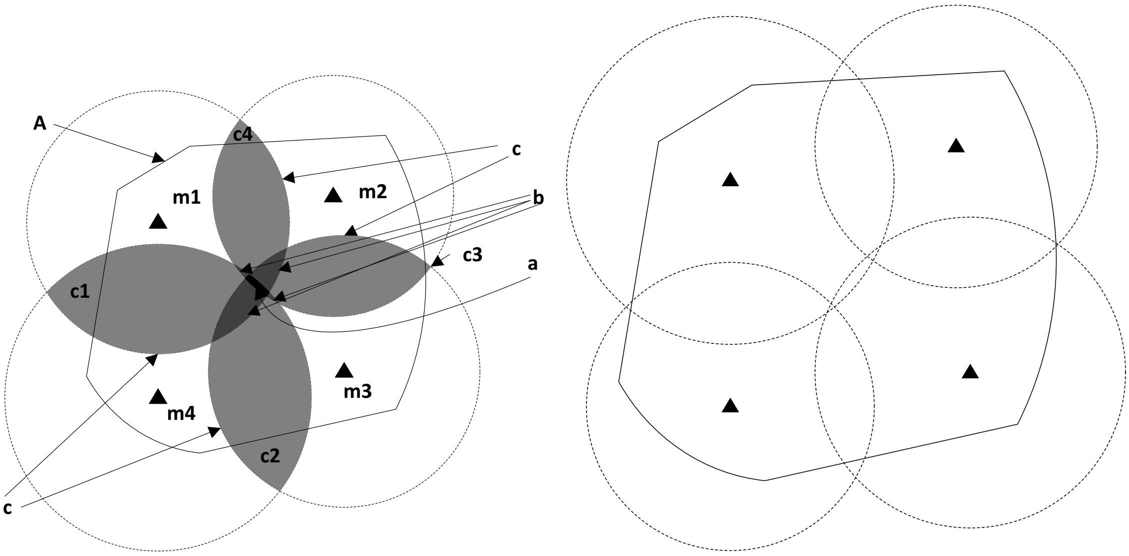
1. INTRODUCTION

In many Muslim countries, there is a very well-known sound that is fired five times a day. This sound is the call-to-prayer or Azan, which is a timely fired call for the five prayers namely Fajir, Duher, Asr, Magrib and Isha [1]. This sound is fired from each Muslim mosque (Masjid). What determines how much sound one can hear (Azan soundscape) in any place is how far one is from Masjids. Masjids positions are determined mainly based on the convenience of access for the habitants in any region. A soundscape is defined as the overall sonic environment in a region [2]. In any soundscape in Muslim countries, Azan is fired from each mosque using loudspeakers that are directed in many directions on top of the minarets of the mosques. The number of mosques in a square kilometer is roughly not less than four. Each one of the mosques fire the same sound at the same time, for that reason any clock that is out of sync in any of the mosques causes a noisy and not so pleasant sound at prayer times. Further, each mosque usually sets its amplifiers to the highest gain independently of other mosques which results in a very loud Azan in some places. These two issues (out of sync. clocks and highest amplifiers gains) can be solved or at least mitigated if a proper setting of a unified call-to-prayers is applied, where gains of mosque's sound-amplifiers are set appropriately and clocks in the mosques are synchronized. In this paper, a unified call-to-prayers framework is proposed that provides a solution to the above two issues. The set of mosques in any region is a distributed real-time system that cooperatively achieves a common goal; namely announcing the prayer times to the residents in that region. However a unified call-to-prayer is not a new idea, it has been applied in many cities in Muslim world; Amman in Jordan is using an FM transmitter [3], Emirates is using satellite broadcasting [4, 3], and Cairo in Egypt where they are using a common transmitter [5, 3]. The unified-call-to-prayer presented in this paper is a novel solution that considers setting amplifiers gains not only firing a unified Azan.

The rest of this paper is organized as follows. A Unified Call-to-Prayer Framework is presented and a problem is formulated in Section 2.. In Section 3. neighbor discovery paradigm is discussed as an important step in proposed framework. A heuristic algorithm to set proper gains for mosques in any region is presented and discussed in Section 4.. Section 5. provides a proof of concept via experimental study. Finally, Section 6. concludes the paper and give a future research directions.

2. UNIFIED CALL-TO-PRAYER FRAMEWORK

In this section, the framework of unified call-to-prayer is given and a proposed solution is discussed.



(a) System Model (b) Modified System

Figure 1. A system of 4 mosques with their (a) random covering areas and (b) a better settings of their covering areas

2.1. Overview of the Framework

As shown in Fig. 1(a), the set of mosques is a group of distributed sites each has its own range of sound broadcasting to its neighbors. The dotted circles represent this range which is the border of desired Sound Pressure Levels. There are several overlapped regions where the sound pressure level is the sum of more than one source. These regions are shown in the figure, A, B and C. In these regions the sound is pretty much a mix of different sound sources which give unpleasant feeling at these regions which is proportional to the number of sources heard. Fig. 1(a) shows only four mosques which is only a simplified sample of the actual distribution of mosques.

These unpleasant feelings in these regions result from any or all of the followings: (1) time differences in Azan firing, (2) several persons who fire the Azan. These two issues can be solved by calling to prayers at the same time and by the same person. Further the range circles can be recalculated to reduce the overlapping areas. More acceptable ranges are depicted in Fig. 1(b).

2.2. Framework Details and Problem Statement

To achieve the required goal of reducing the area of the overlapped areas, this problem can be looked at as an optimization problem. The goal is to minimize the area of overlapped regions while meeting the conditions of satisfying the residents in these regions.

One of the measures used to decide the satisfactions of the residents in these regions is the sound pressure level (SPL). SPL at any distance is proportional to the inverse of the distance from the source. Hence if SPL p_1 at distance r_1 is known then SPL p_2 at r_2 [6] is given for open environment in Eq. 1.

$$p_2 = p_1 - 20log_{10}\left(\frac{r_2}{r_1}\right) \tag{1}$$

Several remarks can be drawn when examining the problem at hand:

R1. There are n nodes in a desired area A, where each node (minaret of the mosque) is equipped with a transceiver, and an omnidirectional loudspeaker (several similar loudspeakers that cover 360° around the minaret).

R2. The link between any two nodes can be affected with several parameters; Temperature, Wind Velocity, diffraction properties and Humidity. The borders of the SPL coverage areas of the two nodes shrink or expand based on these parameters. Sound propagation is affected mainly by the ground surface temp, where direction of the sound propagation bends more toward the colder environment. As of wind velocity, the sound tends to bend toward the lowest speed block of air when the sound propagates in the wind direction and bends toward the highest speed block of air when the sound propagation is not in the same direction of the wind. Sound tends to reflect from hard obstacles when obstacle size is large compared to sound wavelength and tends to bend around when obstacle size is small as compared to sound wavelength. As of humidity parameter, dry air attenuates sound more than humid air does. Further the required SPL at any place is less when the background noise in the region is low.

R3. When looking at the area as a whole there will be regions that are covered by more than one source.

R4. The lack of time synchronization between mosques results in time lapses between Azans heard in overlapped regions. Azan is composed from dedicated words; consequently, the audiences in the overlapped regions hear different words from different sources.

R1 imposes the constraint of covering the desired area A. **R3** gives the objective of our solution for the problem, which is area minimization of the overlapped regions. **R3** and **R4** impose the need of a unified call to prayer and time synchronization between mosques. While **R2** shows the problem dynamics, where the radii of the coverage circles are influenced by the mentioned parameters except wind velocity, where there is no sense in considering the shape of the coverage area as a circle any more.

For the case in Fig. 1(a), the problem can be expressed as a linear program (LP):
Let $\mathbb{OA}$ denotes the sum of the overlapped areas. Then $\mathbb{OA} = a + b + c$, And hence LP can be written as:

Algorithm 1 LP formulation of UCtP problem

minimize $\mathbb{OA}$
such that:
$\mathbb{OA} - m_1 - m_2 - m_3 - m_4 + c_1 + c_2 + c_3 + c_4 = A$

In light of the above LP, the problem at hand requires an enumeration of all possible overlapping between the coverage circles then the optimal solution is the one that gives a smaller overlapped area. This means that the complexity grows exponentially as the number of nodes increases. Since an optimal solution needs a lot of space and time to minimize the overlapped areas, which are indeed not feasible due to the constraints and dynamics of this problem, a faster solution is needed.

Therefore a heuristic algorithm is proposed, in this paper, to provide a fast suboptimal solution to the problem at hand. The algorithm is based on a local decision that is taken in each node based on the state of the neighboring nodes. The algorithm starts by exchanging state describing messages between the nodes, and then each node will decide what gain level will be used for its amplifier. Locally Gain setting Based on Neighboring States Algorithm (LGBNSA) is the name of our algorithm. In the following section we provide the details of this algorithm.

3. NEIGHBOR DISCOVERY

For any node to discover its neighbors, discovery beacon with a highest gain will be broadcasted periodically five times a day ahead of Azan times by delta t. To satisfy the previous goal, we assumed that each node has its own GPS receiver for time synchronization between nodes, and its priority to start beacon broadcasting is based on its ID, as shown in Fig. 2. Each beacon carries the ID of the broadcasting node. Following this procedure each node is capable of recognizing all its neighbors. Failure to receive beacons from other nodes is considered as an indication that the node has no neighbors. Once this happen, this node should switch to its highest gain during scheduled Azan firing. Neighbor discovery algorithm can be classified to two types based on how frequent it is called; short and long term discovery. Long term neighbor discovery can be periodically called for a period of 24 hours, while short term discovery is called five times a day.

Any node that is heard by node i when it transmits its beacon is added to the neighbor table. To calculate the distance of that node from node i a sequence of transmissions is initiated starting by the highest power then starting decreasing that power until it is not heard. At that instant the transmission gain is translated to a logical distance between the two nodes. This distance is used in calculating the logical coordinated of the moving node. For each of the border nodes (that does not have any node in its coverage circle from the border direction) two dummy nodes (radius of the coverage circle of a dummy node is zero) are added to neighbors table.

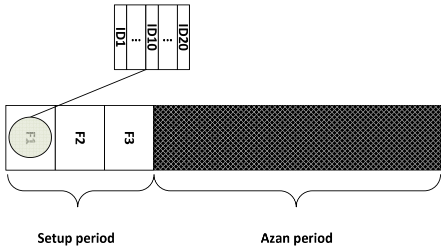


Figure 2. Timing diagram for setup and Azan calling periods

4. LOCALLY GAIN SETTING BASED ON NEIGHBORING STATES ALGORITHM (LGBNSA)

To handle the problem using the proposed algorithm, two cases arise:

1. Number of neighbors for each node is fixed. Based on the result obtained from long term discovery type.
2. Number of neighbors is not fixed which is varying according to short term discovery type.

Each node has what is called a vicinity matrix that includes all nodes of distance 2R or less away. Based on triangulation which means all possible triangles are formed from the node and its neighbors. After forming these triangles a Fermat point is calculated that gives radii of the coverage circles for nodes on vertexes of the triangle. These radii guarantee the coverage of the triangle formed from these nodes. Keep doing this will eventually cover the whole region while keeping the overlapped areas to the minimum possible.

Note that R is not fixed and it does not represent a physical distance on earth, thus the other two vertexes other than the one at focus are dynamically moving away or close to relative to the one at focus. This phenomenon is a logical consequence as a result of the above mentioned parameters. Based on this the node at focus sends beacons to other nodes in its adjacency matrix to determine how far a way they are. Then a new logical coordinates for these nodes are formulated and implemented in calculation of Fermat point. Fig. 3 clarifies this idea.

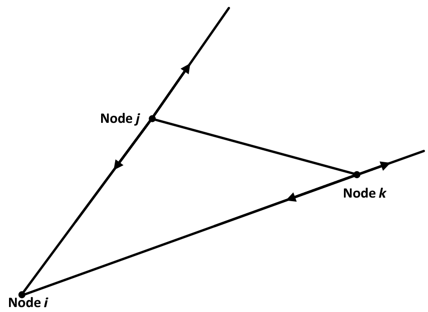


Figure 3. Logical Coordinates of nodes j and k as seen from node i

The new point of the virtually moving node can be simply calculated from the line equation, assuming the movement is only happen along the physical line between the nodes. While it is possible for the node to show an illusion of coordinates that are not on the same line, we did not consider it in this paper and we reserve that for a future work. Let r denotes the distance between the two nodes n_i at point (x_i, y_i) and n_k at point (x_k, y_k). Let d denotes the logical distance between the new location of node k at point (x_k^*, y_k^*) and node i. Then (x_k^*, y_k^*) can be calculated as in Eq. 2.

$$y_k^* = y_i + d\frac{y_k - y_i}{r}, x_k^* = \left(y_k^* - y_i + \frac{y_k - y_i}{x_k - x_i}x_1\right)\frac{x_k - x_i}{y_k - y_i} \tag{2}$$

Similarly, Eq. 2 is used to find the logical coordinates of node j, (x_j^*, y_j^*). To calculate the radius for each of the vertexes ((x_1, y_1), (x_2, y_2) and (x_3, y_3)) under consideration, we need to find the Fermat point which is done according to the work in [7]. Their equations (3) for finding Fermat point (x_F, y_F) is repeated here for completeness of the work.

$$x_F = \frac{K_1K_2K_3}{2S\sqrt{3}d}\left(\frac{x_1}{K_1} + \frac{x_2}{K_2} + \frac{x_3}{K_3}\right), y_F = \frac{K_1K_2K_3}{2S\sqrt{3}d}\left(\frac{y_1}{K_1} + \frac{y_2}{K_2} + \frac{y_3}{K_3}\right) \tag{3}$$

where,

$$S = |x_1y_2 + x_2y_3 + x_3y_1 - x_1y_3 - x_3y_2 - x_2y_1|$$

$$r_{jl} = \sqrt{(x_j - x_l)^2 + (y_j - y_l)^2} \text{ for } \{j, l\} \in \{1, 2, 3\}$$

$$K_1 = \frac{\sqrt{3}}{2}(r_{12}^2 + r_{13}^2 - r_{23}^2) + S$$

$$K_2 = \frac{\sqrt{3}}{2}(r_{23}^2 + r_{12}^2 - r_{13}^2) + S$$

$$K_3 = \frac{\sqrt{3}}{2}(r_{13}^2 + r_{23}^2 - r_{12}^2) + S$$

$$d = \frac{1}{\sqrt{3}}(K_1 + K_2 + K_3)$$

Then for node i the distance from Fermat point, r_{iF}, is calculated as:

$$r_{iF} = \sqrt{(x_i - x_F)^2 + (y_i - y_F)^2} \tag{4}$$

Assuming that $r_1 = 1$, $p_2 = p_F$, and using the result of above equation (4), $p_i = p_1$ can be found from Eq. 1.

Algorithm 2 Locally Gain setting Based on Neighboring States Algorithm (LGBNSA)

Input: node i and its neighbors
Output: node i with adjusted radius
$R_i \leftarrow$ max{0, max. distance from dummy nodes if any}
for all nodes in neighbor table of i **do**
  Construct a triangle
  Compute the distance from i to Fermat point of the triangle
  if R_i is less than the computed distance **then**
    $R_i \leftarrow$ computed distance
  end if
end for

In this paper, where the goal is to shed light on the existing problem, we made some assumptions:

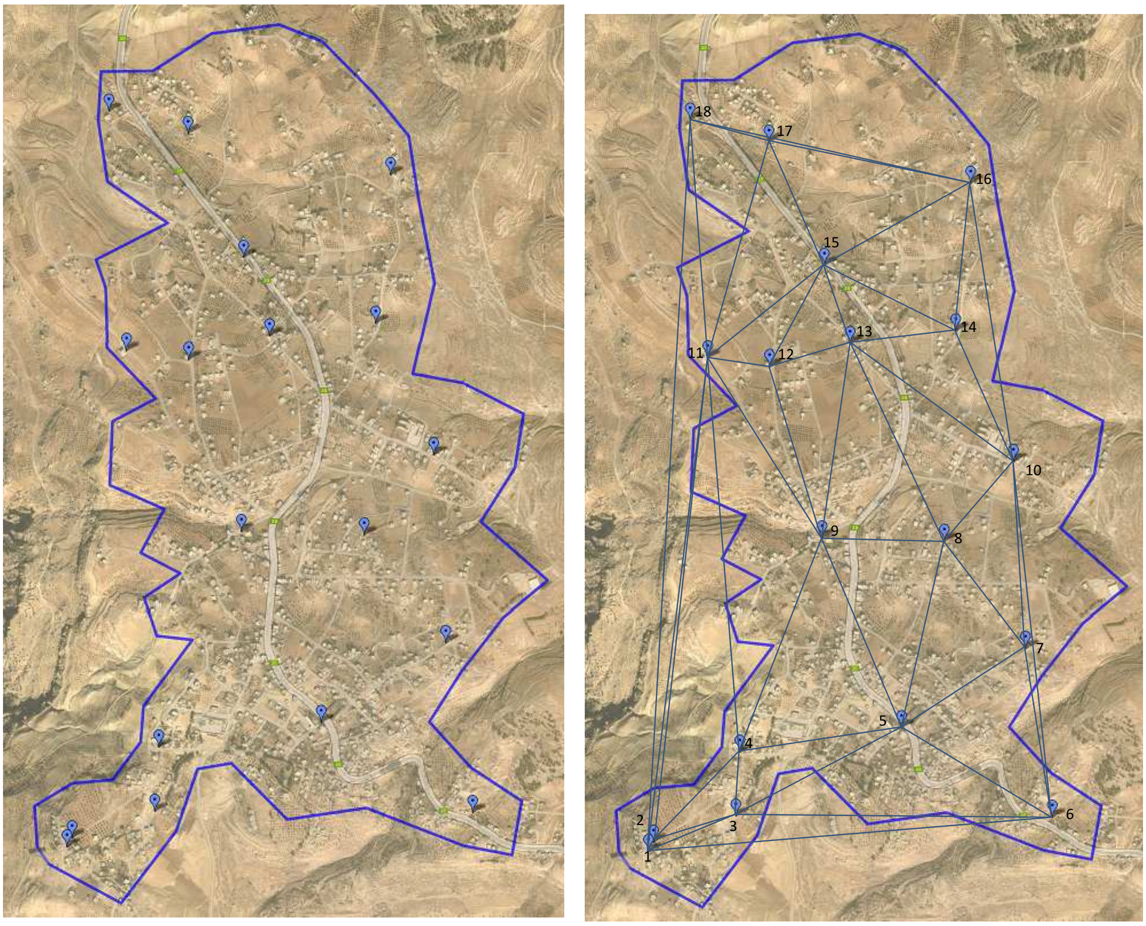
- Neighbors are fixed and known to any of the nodes.
- The region that contains the mosques is a flat area, i.e., there is no mountains or valleys in the region.
- Mosques sound levels are the same on all directions and form a circle centered at the specified mosque.

5. EXPERIMENTAL STUDIES

In this section, we present mosques transmission radii for actual mosques on earth. Then we apply the proposed algorithm on that distribution of the mosques and compare the results. To our knowledge, no researchers have been discussed this problem before. Fig. 4(a) shows the distribution of mosques in Ainalbaida region that lies in the southern part of Jordan. The residential area of this village is 1800 meters wide by 3100 meters long. Eighteen mosques are distributed almost randomly in this area, i.e., not according to the sound levels distribution around the mosque rather than the convenience of access for the residents. Table 1 reports the conventional coordinates of the vertexes of the mosques. Note that the distances between mosques in this coordinate system is a representative system of the actual coordinate system. The mosques are numbered in order as Fig. 4(b) shows; the origin of coordinates is placed in the bottom-left corner of the figure. Please, bear in mind that the positions cannot be swapped to any new location and the coordinates are estimated with respect to the (x,y) reference frame.

Fig. 4(b) is generated by performing a 2D Delaunay triangulation [9] on a set of eighteen mosques. The resulting diagram consists of twenty nine triangles distributed as shown in Fig. 4(b). Delaunay triangulation has the property that the circumcircle of any triangle in the triangulation contains no mosque in its interior. The centers of the circumcircles are then connected to each other in which they all produce a Voronoi diagram [10] which is a dual of the Delaunay triangulation.

To apply LGBNSA, the neighbors of the mosques are as shown in Table 2. Note that, in this table any neighbor that is far away by more than 2R (R considered here as 200) is dropped from the list of neighbors and hence any triangle formed with this neighbor is also dropped from triangles used in calculating Fermat points. For example



(a) Distribution of mosques in Ainalbaida region [8]

(b) x,y Coordinates and Delaunay triangulation of Ainalbeada mosques [8]

Figure 4. Mosques in Ainalbaida region (a) Distribution and (b) triangulation

the triangle formed by mosques 1, 3, and 6 in Fig. 4(b) is not considered in any further calculation because distances between 1 and 6; and 3 and 6 are greater than 200.

Note that for any mosque where its neighbors list is empty, its radius is the highest (200 in our example).

Fig. 5(a) shows the circles that are drawn around each mosque and represent its covering region. Fig. 5(b) shows the current covering circles of the mosques, where each mosque uses its max amplifier gain (equivalent to 200 in our case). We showed only some of them in order to keep the figure as clear as possible although each of the mosques has the same circle centered on it.

Using the information in Table 2, the sum of radii squares is around 372333. While for the radii in Fig. 5(b) the sum of their squares is 720000. The number for the calculated radii is small compared to the current system. This number reflects the sum of sound levels in the region covered by the given mosques, i.e., proportional to the areas of the covering circles. That means the overlapped areas are larger than in current system from that calculated by the proposed algorithm. This number is also proportional to the power consumption by the mosques amplifiers.

6. CONCLUSION AND FUTURE WORK

Call-to-prayer in Muslim world is an important timely fired sound. This sound is triggered five times a day in a noisy and distracting way if not correctly synchronized and unified. In this paper a novel framework of unified call-to-prayer was proposed. The problem was formulated, analyzed, and a general solution was proposed that is dependent on setting a suitable gain for the different mosques amplifiers. This work can be implemented to serve many other sound generating facilities like public school, churches, disaster announcement.

As a future work, the transmitting of unified call-to-prayer will be studied to achieve the requirements of convenience and covering habitants' areas. A suitable terrain and local environment models can be applied to get more accurate

Table 1. XY coordinates of Ainalbeada mosques

Mosque	X	Y
1	55	71
2	59	81
3	132	103
4	135	159
5	277	180
6	409	102
7	385	250
8	314	344
9	207	347
10	375	414
11	107	505
12	161	497
13	231	517
14	324	528
15	210	586
16	337	660
17	161	695
18	92	713

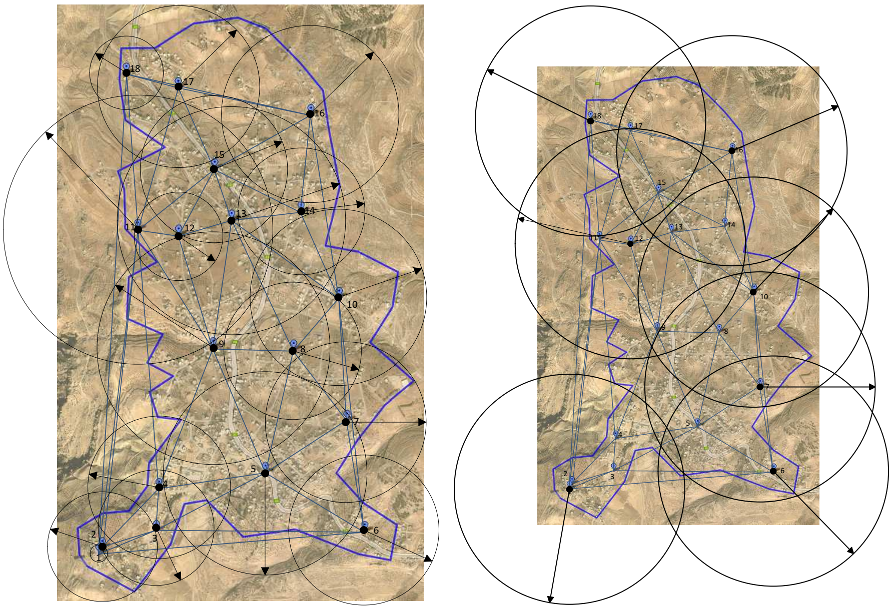
Table 2. Neighbors and calculated radii of Ainalbeada mosques

M i	Set of neighbors (j, k)	Radius
1	(2,3)	11.5
2	(1,3), (3,4)	72.7
3	(1,2), (2,4), (4,5)	77
4	(2,3), (3,5), (5,9)	95
5	(3,4), (4,9), (9,8), (8,7), (7,6)	135.5
6	(5,7)	100
7	(5,6), (5,8), (8,10)	107
8	(5,7), (7,10), (10,13), (13,9), (9,5)	91.5
9	(4,5), (5,8), (8,13), (13,12), (12,11)	155
10	(7,8), (8,13), (13,14)	117.5
11	(9,12), (12,15), (15,17), (17,18)	179.3
12	(9,11), (11,15), (15,13), (13,9)	59
13	(9,8), (8,10), (10,14), (14,15), (15,12), (12,9)	152
14	(10,13), (13,15), (15,16)	84.5
15	(11,12), (12,13), (13,14), (14,16), (16,17), (17,11)	98
16	(14,15), (15,17)	118
17	(16,15), (15,11), (11,18)	108
18	(11,17)	49

distances between mosques in the neighborhood. Further, any loudspeaker on the minaret of any mosque can be taken into account which produces a non-circular covering region.

REFERENCES

[1] T. S. Lee, “Technology and the production of islamic space: the call to prayer in singapore,” *Ethnomusicology*, vol. 43, no. 1, pp. 86–100, 1999.



(a) Calculated radii of the mosques based on the proposed algorithm [8]

(b) Coverage circles of the mosques in Ainal-baida [8]

Figure 5. Mosques and their covering regins. (a) Calculated using the proposedlgorithm and (b) actual covering circles

[2] J. D. Porteous and J. F. Mastin, “Soundscape.” *Journal of Architectural and Planning Research*, 1985.

[3] “http://www.uaeinteract.com/docs/ministry_announces_unified _call_system/13899.htm,” last accessed: December, 7, 2013.

[4] “http://www.awqaf.ae/service.aspx?lang=en&sectionid=19&refid=1348,” last accessed: December, 7, 2013.

[5] “http://www.egyptindependent.com/news/one-voice-many-mosques-call-prayer-unified-muezzins-defy-government-orders,” last accessed: December, 7, 2013.

[6] D. Bies and C. Hansen, *Engineering noise control: theory and practice*. Taylor & Francis, 2009.

[7] A. Y. Uteshev, “Analytical solution for the generalized fermat-torricelli problem,” *arXiv preprint arXiv:1208.3324*, 2012.

[8] “Tafila, jo. (03 feb. 2014). google maps. google. retrieved from https://maps.google.com/maps/ms?msid=203417662707219167682.0004e6fa615a01ba6136a&msa =0&ll=30.784244,35.598621&spn=0.049699,0.090895.”

[9] D.-T. Lee and B. J. Schachter, “Two algorithms for constructing a delaunay triangulation,” *International Journal of Computer & Information Sciences*, vol. 9, no. 3, pp. 219–242, 1980.

[10] F. Aurenhammer, “Voronoi diagramsa survey of a fundamental geometric data structure,” *ACM Computing Surveys (CSUR)*, vol. 23, no. 3, pp. 345–405, 1991.