Comparison the Various Criteria in Wireless Network Topology Optimization Task

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Abstract

The quality of the topology of wireless networks is assessed using various criteria. This requires previously making a proper choice of the assessment criteria and then selection the optimization algorithm. This paper presented a number of criteria for the assessment of wireless networks and discusses the results of comparative analysis optimal topologies for different criterion. It also discusses the brute force algorithm and its possible application for the design of the wireless networks topology and the computational complexity of this process. In order to apply the brute force algorithm the task of wireless network topology optimization is defined as discrete optimization task. It has been shown that the proposed approach is invariant respectively to the various criteria. The workstation with two Quad Core CPU Intel Xeon co-processors and 7120P Intel Xeon Phi co-processor with 60 cores has been used for computation experiments. Finally we showed the visual presentation for all decisions.

Keywords: brute force algorithm; wireless networks' topology optimization; visualization.

1 Introduction

Nowadays many people use mobile electronic devices for connection with wireless network and communication with each other and also for access to the telecommunications services. Most popular of them are: E-government; E-education; E-health; E-Commerce.

Electronic Government supports the official interactions between government and citizens by means of modern information and communication technologies. There are some subdivisions of such communications which depends on the interactions subjects: government, citizens, employees and business.

Electronic Education is a very important technology for teaching and learning which allow using any electronic gadgets to support all stages of educational process. There are many terms relation with the learning via the Internet: distance education, electronic learning, on-line learning, the Internet learning and some others.

Electronic Health allows the developing countries to increase the efficiency of medical service and decrease medical budget ("World Health Organization," n.d.).

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Electronic Commerce is supposed that there are some business transactions between actors, either as business-to-business, business-to-consumer, consumer-to-consumer or consumer-to-business. All this transactions are aimed to buying and selling of goods and services, or the transmitting of funds or data, over a network, primarily by the Internet. E-commerce is supported by some technologies such as mobile commerce, electronic funds transfer, supply chain management, Internet marketing,on-line transaction processing, electronic data interchange (EDI), inventory management systems, and automated data collection systems. Of course, modern electronic commerce widely uses the World Wide Web for at least one part of the transaction's life cycle although it may also use other technologies such as e-mail ("E-commerce," n.d.).

All kinds of electronic services are strongly influence on the level of society development and that must be used by young democracies. And all this advantages we can get if existence the infrastructure of wireless networks.

2 Telecommunication Technologies in Myanmar

The population of Myanmar in 2016 is about 55 Millions, 65 percent is rural and 35 percent urban; most of the rural areas are actually agricultural villages("Worldmeters," n.d.).

In 2006 - 2010, Myanmar had established the first national ICT (information and communication technology) master plan to build telecommunications services for developing society. The works scopes were: ICT infrastructure, ICT industry, ICT HRD, E-government, E-education and Awareness, E-commerce. In 2016 the ICT development of Myanmar ranked 140 among 175 countries ("ICT Development Index 2016," n.d.). ICT technologies can reduce the digital difference between the urban and rural areas of Myanmar and to get better communication of citizens. Developments in ICT are changing all aspects of societies. One of the most important ones is the e-Government services.

Myanmar citizens have a low level of Internet access due to lack of infrastructure. It is necessary to improve the speed, quality, coverage and reduce cost of Internet. Most of users go on-line via cell phones, which are comparatively more affordable. World Internet Statistics of June 2012 showed that Myanmar had over 534,930 Internet users (1.0% of the population) with the vast majority of the users hailing from the two largest cities, Yangon and Mandalay("Internet in Myanmar," n.d.). Most of the country's 40,000 Internet connections were ADSL circuits, followed by dial-up, satellite terminal and WiMax. The Internet users significantly increased to 12.6% in 2015 with the introduction of faster mobile 3G Internet by transnational telecommunication companies - Telenor Myanmar (Norwegian group), Ooredoo Myanmar (Qatar-based) and later national Myanmar Post and Telecommunications (MPT). Nowadays Internet networks upgrades to 4G in the largest cities of Myanmar ("Internet World Stats," 2016).

Table 1: Internet Usage and Population Statistics

Year	Internet Users	Population	Percentage
2000	1,000	47,388,357	0.002%
2008	40,000	50,864,410	0.078%
2009	108,900	51,199,866	0.212%
2010	110,000	51,551,369	0.213%
2012	534,930	52,334,626	1.02%
2015	7,100,000	53,667,157	13.23%
2016	11,000,000	54,106,691	20.33%

In 2013, the government started taking steps to open up the telecommunications market, resulting in the reduction of consumer prices and a rapid growth in the number of subscribers, as well as the expansion of the country's infrastructure. In November 2015, Ericsson named Myanmar the world's fourth fastest-growing mobile market. As of June 2015 a mobile phone use 54.6% of citizens, compared from less than 10% in 2012.

National backbone has fiber link between major Cities. Cross border fiber links are connecting Myanmar with India, China and Thailand by SEA-ME-WE 3 submarine cable and satellite ("The Irrawaddy,"n.d.).

3 Modern Challenges for Myanmar ICT

Citizens in major cities have good access to ICT services, but in rural areas this is far from satisfactory. In other words, without an adequate infrastructure, the entire ICT sector will not be able to achieve their goals.

When compared to its regional neighbors, the need in the development of broadband Internet access in Myanmar becomes even clearer. One of the biggest challenges facing Myanmar concerns the roll-out of mobile infrastructure. Although as per current forecast, some $5,800$ towers will have been made operational in 2015, serving the 56.3 million people who live in Myanmar will require around $20,000$ towers to be built over the next few years. The mobile network population coverage is expected to grow from the current level of 12% to 70% by 2017; by 2020, 95% of people must be covered. Another objective is to increase the uptake of broadband Internet to at least 25% by 2018 and the number of base stations should grow to $17,300$ sites by 2017 ("Alliance for Affordable Internet," 2015).

Installation of fixed lines has expanded mostly in major cities and highly populated areas, with high installation costs and geographical barriers in rural areas inhibiting installation and complicating maintenance of physical infrastructure such as cables [Kee-Yung Nam et al., 2015]. Wireless technology can cover a wide range of areas without using cables and its equipment is relatively easy to install. One of the possible decisions of this problem is using the WiMAX technologies.

The WiMAX is based on 802.16 standards. It serves as both a fixed and wireless access technology. Coverage of 50 km, that enough to provide connections in major cities and capacity of around 70 Mbit/s is a reality with this technology. But at higher speeds over greater distances and for a greater number of users and WiMAX as access technology is offered in distances of 5 to 10 km. WiMAX has the ability to provide service even in areas which are inaccessible for traditional wired infrastructure due to the ability to overcome the topological limitations.

4 Optimization the Topology of Wireless Networks

Topological designing of wireless networks supposes the determining the position of all network elements. We can define this task as a discrete optimization problem and solving it by using the brute force algorithm.

In order to apply the brute force algorithm the task of wireless network topology optimization is defined as following:

1. Let define a final set of N network elements {A} and a set of K their possible positions {P}. In practice the number of positions K is much bigger than the number of elements N.

2. During the distribution of the elements {A} on to positions {P} it is necessary to provide an extremum of some functional F. In the result of optimization we define the solution of the problem as N-dimensional vector D [Aye Min Thike et al., 2016], which elements belong to {P}:

$$D = (P_1, \cdots, P_N), P_i \in \{P\}, \forall i = 1, N \tag{1}$$

$$F(D) \to max \tag{2}$$

This problem definition allows the brute force algorithm to be implemented also as a multi-threaded application [Posypkin & Sigal, 2006].

The quality of the wireless networks topology may be assessed using various criteria. If we need to optimize them simultaneously this task transforms to multi-criterial.

A choice of the criteria defines the decision. Below we present a number of criteria for the assessment of efficiency of wireless network topology and the results of comparative analysis the optimal topologies for them. It also discusses the brute force algorithm and its possible application for the design of the wireless networks topology and computational complexity of this process. Finally we present the visual presentation for all decisions.

For optimal spatial arrangement of antennas it is necessary to define the criteria using the following considerations:

1. Power of signal *(S)* receiving at a certain point R is inversely proportional to the square of the distance $\rho = \| R - T \|$ between this point and the point where the transmission antenna is located *(T)*; S_0 is the transmitter output power:

$$S(T,R) = S_0/\rho(T,R)^2 \tag{3}$$

2. We assume that the reliable transmission the information between the network nodes is provided under the following condition:

$$R \leq R_{\max} \tag{4}$$

3. The set $\{T\}$ represents the particular coordinates (x,y) of L cities locations and a quantity of inhabitants in them (C):

$$T_i = (x_i, y_i, C_i) \tag{5}$$

In this paper we consider utilization one of the following equations as the main criterion of topology optimization.

1. Maximizing the number of residents having the access to network services, without consideration the signal power:

$$F_1(D) = \sum_{i=1}^{L} V(T_i, D).C_i \to max \tag{6}$$

In this equation V is the visibility indicator for the city T_i:

$$V(T_i, D) = \begin{cases} 1, if\ \exists P_j \in D : \rho(T_i, P_j) \leq R^j_{\max} \\ 0, otherwise \end{cases}$$

2. Maximizing the number of residents which placed in zones with high power signal:

$$F_2(D) = \sum_{i=1}^{L} (\max_{P \in D}\ S\,(T_i, P).C_i) \to max \tag{7}$$

Thus, in case of the presence of several antennas, the antenna having the maximum signal power is selected (3).

3. Maximizing the square of territory with high power propagated signal:

$$F_3(D) = \Delta\ \cdot \sum_{i=1}^{M} \sum_{j=1}^{M} (\max_{P \in D} S\Big(\Delta_{\mathrm{i,j}}, P\Big)) \to max \tag{8}$$

for M-dimensional grid, each part of which is Δ ($\Delta_{\mathrm{i,j}}$ is the center point of this cell), its size is $|\Delta| = \Omega/M^2$, where Ω is the square of the land.

The city residents are not taken into account in this criterion.

4. Maximizing the number of residents having the access to network services with the consideration of the space distribution of cities' residents (like F_1):

$$F_4(D) = \sum_{i=1}^{M} \sum_{j=1}^{M} \theta(i,j) V(\Delta_{\mathrm{i,j}}, D) \to max \tag{9}$$

$$\theta(i,j) = \sum_{k=1}^{L} C_k.e^{-\rho(T_i, \Delta_{\mathrm{i,j}})} \tag{10}$$

Next examples show the difference between the decisions based on this criteria.

5 Computational Experiments

For solving the topology optimization problem we use brute force algorithm in sequential and parallel implementation, and as a testing task - wireless networks topology for a real fragment of Myanmar map. Wireless network is based on two types of stations which using as a transmitter and receiver for telecom signals (Table II).

Table 2: Parameters of Stations

Type	$R_{\max}(km)$	S^0
A_1	10	1
A_2	20	4

The station of first type costs \$100 (contingently) and can ensure reliable communication at the maximum distance 10 km, the station of the second type costs \$200 and provides reliable communication at 20 km.

We provide experiments for different sets of antennas-common number always equal 3, but we combine it from different quantities of two types of stations.

Map on fig.1 shows the real fragment of Myanmar map (50*50 Km), which used for the computational exercises. There are 21 settlements on it.

Figure 1: Location of Town (Green) & Villages (Red)

We use the simple and compact tabulated description of map. The coordinates of the settlements and corresponding population are given in Table III.

Table 3: Description of the Map Fragment

Town	x	y	Population(C)
1	3.7	2.5	310000
2	10.3	32.9	190000
3	8.9	48.2	310000
4	29.4	37.1	200000
5	36.1	3.1	220000
6	43.7	34.5	110000
7	48.8	21.8	110000
8	2.5	3.4	4000
9	8.7	15.3	1500
10	11.2	33.9	2000
11	10.3	47.5	5000
12	18.9	44.6	500
13	33.8	3.2	1300
14	27.1	8.3	800
15	25.1	22.5	4500
16	29.3	25.7	2500
17	31.9	36.1	1700
18	42.9	11.9	3500
19	38.4	18.7	4300
20	47.6	17.5	1400
21	46.3	32.3	1600

The required decision representing the set of network elements {A} may consist up to three antennas – N=3.

The set of positions {P} is defined by dividing the X and Y axes by M_X and M_Y steps respectively. The antennas can be allocated only in the middle of such squared. In order to simplify the task consideration both numbers are equal: $M_x = M_y =$ M. Thus the number of antenna positions is equal to K=M^2.

Thus, the topology of the wireless networks should be defined as the optimum distribution of antennas (Table II) between cities (Table III).

6 Program Implementation and Results

The serial application has been implemented using programming language C++. The computational complexity of the brute force algorithm depends on the number of the analyzed variants [Aye Min Thike et al., 2017]. In this example, the number of the topology variants is $(M^2)^N$. For this large number of variants the parallel programming is being employed in the environment of Intel Parallel Studio 2017 and OpenMP library.

Technology OpenMP (Open Multi-Processing) is the most popular for the designing of multi-threaded programs [Evtushenko et al., 2009]. It allows creating the multi-threaded applications for multiprocessor or also for multi-core with shared memory.

If the program is realizing the brute force algorithm then all the calculations in threads are data independent. This is due to each thread estimates different variants of the topology. But there is only one common variable for all threads, it is *current record*. It means that if the value of criterion for a certain variant is less than the value in *record*, this value must be redefined. Of course, we can collect the local records after all threads finish their work and thus minimized the interaction between them.

The grid dimension equals $M^2 = 30^2 = 900$ in all cases. The number of analyzed positions is $(M^2)^N = 900^3 = 7.29 * 10^8$. The computational time was varying from 2 seconds to one hour. The computational time depends not only from quantities of positions and antennas, but also from type of criterion. The solution using criteria F_2 and F_4 requires a little bit longer time than using the criterion F_1 whereas calculation time for function F_3 is much longer. Next pictures show the optimal topology for different criteria.

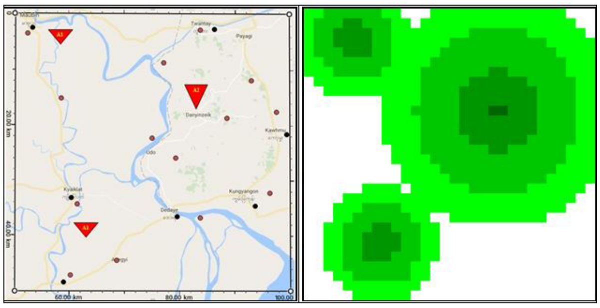

Figure 2: Decision for criterion F_1

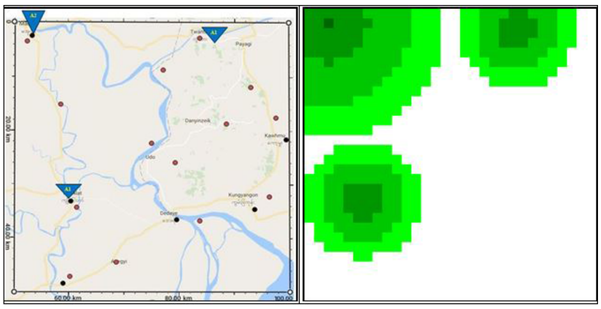

Figure 3: Decision for criterion F_2

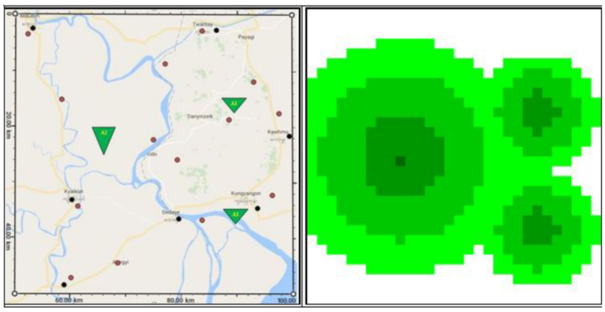

Figure 4: Decision for criterion F_3

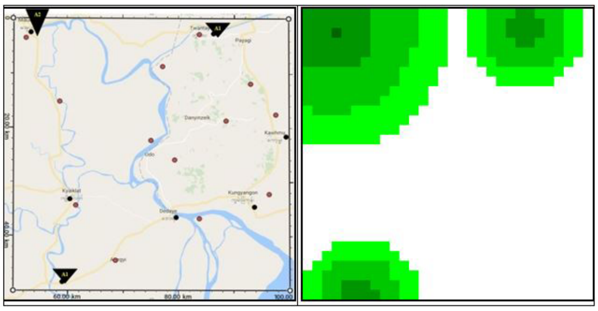

Figure 5: Decision for criterion F_4

Figures 2-5 shows the results of optimization for the 3 antennas network segment. The optimum allocations of antennas are shown on the background of the Myanmar map fragment. Since two different types of antennas are used for the topology synthesis, they are also marked by different signs in the figures - the small triangles indicate the positions of the antennas A_1 whereas the large triangles indicate the position of the antenna A_2.

Graphic presentations the results show that the optimal topologies for the criteria F_2 and F_4 are quite similar. The solutions for criteria F_1 and F_3 are also quite similar, but are much different from previous pair. It is necessary to remark-visual presentations the signal distributions for optimal topologies give us the additional instrument for their design and comparison.

The results of the numerical comparison of the optimal topologies are shown in Table IV. For all the variants of decisions (columns topology) the values of another three criteria have been defined. It can be seen that the value of criterion is marked by color.

Table 4: Comparison the Various Criteria

	F_1 topology	F_2 topology	F_3 topology	F_4 topology
F_1	1484600	728800	523500	855800
F_2	26748	1479594	16187	698940
F_3	87.7	63.6	89.4	65.7
F_4	32019	422485	20062	620430

It is interesting to note that solutions with a similar topology have fairly close values for all criteria.

Some words about the computational platform. We use the workstation having two Quad Core CPU Intel Xeon for all calculation, excepting the criterion F_3, where 7120P Intel Xeon Phi co-processor with 60 cores has been used. All threads run simultaneously in the parallel application and each of them uses one core. Hyper threading regime has not been used for the calculation.

7 Conclusion

The examples presented in this paper demonstrate that the brute force algorithm can be effectively implemented for the design of the optimum wireless networks topology. Moreover, it has been shown that the proposed approach is invariant respectively to the various criteria. The application does not require a serious modification if the optimization criteria are changed.

The further work will investigate the applicability of the proposed algorithm for analysis and design of the topology for the wireless network having the directional antennas. It is expected that the computational complexity of the algorithm will be significantly increased which will require implementation of Intel Xeon Phi co-processor.

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