OPTIMALIZATION OF BEACON SELECTION FOR LOCALIZATION IN WIRELESS AD-HOC NETWORKS

M. Matula[1], J. Dúha[2]

Department of Telecommunications and Multimedia, Faculty of Electrical Engineering University of Žilina
Veľký diel, 010 26 Žilina, tel.: +421 41 513 2241
mail: [1]matula@fel.utc.sk, [2]duha@fel.utc.sk

Summary In this paper we engage in optimalization of convenient beacons for localization position of a node in the ad-hoc network. An algorithm designed by us localizes position of moving or static node by RSS (Received Signal Strength) method and trilateration. At first, localization of unknown node runs by combination of all beacons. Than optimalizating algorithm reduces the number of beacons (and repeats localization), while only three left. Its reduction is based on highest levels of received signal strength. It is only when signals are from the nearest beacons. Position localizating exactness is statistically interpreted from all localization by beacons combination and its repeating.

1. INTRODUCTION

Mobile wireless ad-hoc networks are dynamically changing, autonomic networks composed of equal nodes without fixed infrastructure. Nodes communicate by radio channel in ad-hoc networks directly (single-hop) or by more communicating nodes (multi-hop) without centralized control. These networks are used in strategic areas, for example in army, during rescue operations (disasters), conferences (convention hall, campus, hospitals), private company networks, home networks, special sport activities, etc. Ad-hoc network is composed of nodes, which are presented by notebooks, personal computers, mobile digital assistants (MDA), personal digital assistants (PDA), intelligent cell phones, access points (AP).

WSNs (Wireless Sensor Network) are specific category of ad-hoc networks which are almost static and extensive network with amount sensor nodes.

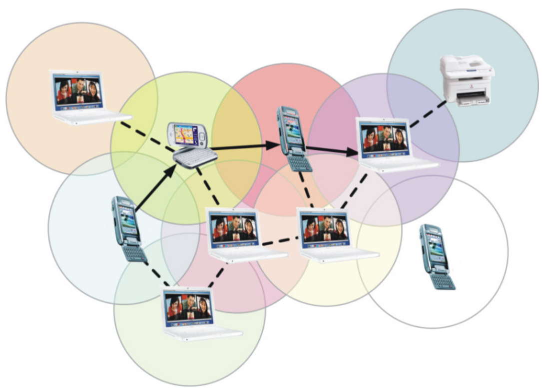

Fig. 1. Wireless ad-hoc network.

Nowadays new applications and services, where most of all require a knowledge of nodes position in the network. Many algorithms of position localization exist in wireless ad-hoc networks and the point is to find optimal solution for given networks conditions with the most exact position localization of an unknown node.

These algorithms could be based on methods of position localization, which are divided to three categories:

- Signal strength based methods (Proximity, RSS, Fingerprint)
- Direction based methods (Angle of Arrival / Direction of Arrival)
- Time based methods (Time of Arrival, Time Difference of Arrival)

2. THEORY

In this paper we engage in position localization based on RSS method, whereas simple implementation exist in practice (because it is possible to pursue level of received signal strength by most of radio devices). The accuracy of this method (RSS) could be enough for many cases (even if it is considered to be the most inexact ones).

Statistic methods are necessary for increasing probability of position localization in case of using RSS method, forasmuch as stochastic noise character effecting on broadcast signal.

Propagation of radio signal works in real environment, whereby the beacon broadcast 10dBm power level (see Fig. 2). In this case, it was NLOS (Non Line Of Sight) environment generated by designed function, which can help us to generate power level also in other position localization simulations (Matlab environment).

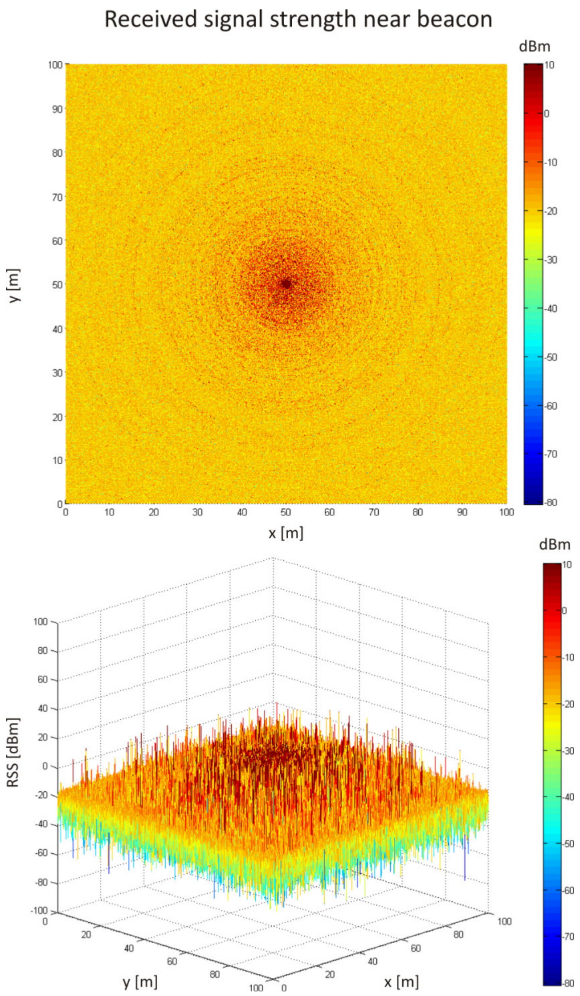

Fig. 2. Signal strength distribution in beacon transmitter area.

We obtain distance between beacon and node by receiving signal strength and we make trilateration using three distances from beacons, which are not on the straight line. When we determine position by trilateration, we use circles formula (2D) defined as:

$$d^2 = (x - x_1)^2 + (y - y_1)^2 \ [\mathrm{m}], \qquad (1)$$

where x_1 a y_1 is circles dislocation from central point, x is x coordinate and y is y coordinate. In case, that we know position data of at least three points, where i means label of individual nodes, we can write:

$$d_i = \sqrt{(x - x_i)^2 + (y - y_i)^2} \ [\mathrm{m}]. \qquad (2)$$

We obtain a node by trilateration, which gives us position of the node (see Fig. 3).

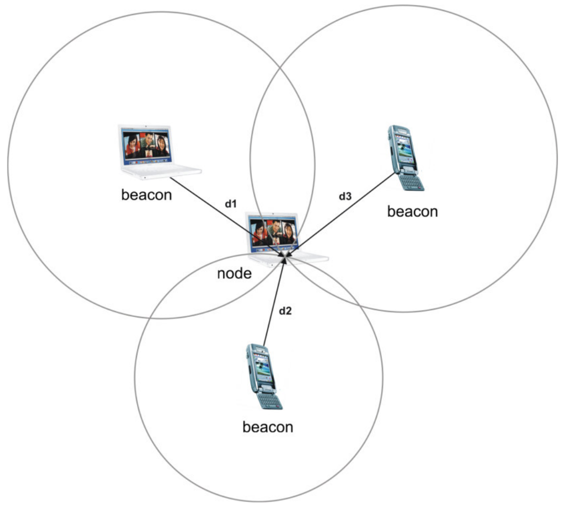

Fig. 3. Practical demonstration of trilateration in mobile ad-hoc networks.

As it was indicated, it is necessary to use statistic methods to increase statistic precision of position localization in the case of RSS. Relation identification between transmitter and receiver is task of statistic processing, which have partly determinated and partly stochastic character. It is possible to increase probability of real position estimation, by correct setting of statistic models (for example models to set position – by using of histograms in our case).

It is necessary to make provision for some criteria's during a choice optimalization of proper beacons:

- type of an expected method for position localization (trilateration, triangulation, APIT, ToA, …)
- correct choice of (statistic) parameter – criterion (width CI – Confidence Interval, minimal mean value of distances, standard deviation, ...)
- environment type and its extensiveness (indoor/outdoor, LOS/NLOS,…)
- system massiveness (number of beacons, nodes)
- computing severity (time severity dependence on designed algorithm, system and environment massiveness if we mean real system. Distributed calculation can helps during simulation).

3. EXPERIMENTAL

The power level dependence of received signal on distance was generated in Matlab environment. It contains compositions of attenuation by propagation, attenuation by shadowing (long-time fading) of short-time fading and noise (AWGN). Attenuation by propagation was realized by exponential decrease, attenuation by shadowing by signal generated with logarithmic-normal distribution. Short-time fading was generated by integrated

Matlab function *ricianchan* (which allows to generate Rice and Rayleigh channel) and AWGN channel (*awgn* function in Matlab) was used to produce noise.

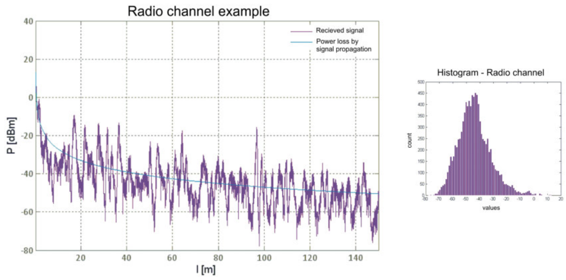

Fig. 4. Wireless radio channel.

The simulation, which can be used to generate an environment, allows to localize a position by direct method, too. Direct method (DM) means determination of position by trilateration, which results in one point. Chances of data statistic processing, creating localization algorithm (trilateration, triangulation, APIT – Approximate Point In Triangulation, ToA, ...) and algorithm for optimalization of beacon selection, which was used for position localization of unknown node, are opened by this.

The node could measure the level of received signal strength from beacons in real environment, which is in direct communication proximity. Obtained data was about beacons position and Doppler shift between unknown node (in case it was a mobile node) and beacons. The simulation of sequential selection of beacons is realized in two steps for needs of localization.

At first step are perform localization by all beacons, which are in the communication range of signal coverage area to node. We reason all combination of beacons for measurement estimation of position by direct method. For each combination of three beacons (except of those which are on ones line) are perform number of repeating estimation position measurement. Simultaneously was computing mean values of distances (mean values of received signal strength) individual beacons from node. These mean values are used for selection of next beacons generation, which are used for node localization.

At second step are realized the optimalization of beacons selection for localization. Optimalization – reduction number of used beacons was follow. For simulation are keeping only those beacons from which mean value of received signal strength come across as most highly and least are removing. If beacons are more than eight, reduce three of them. If beacons are eight or less than eight, reduce two of them, until only three beacons left. In case if four beacons stay, shutdown only one.

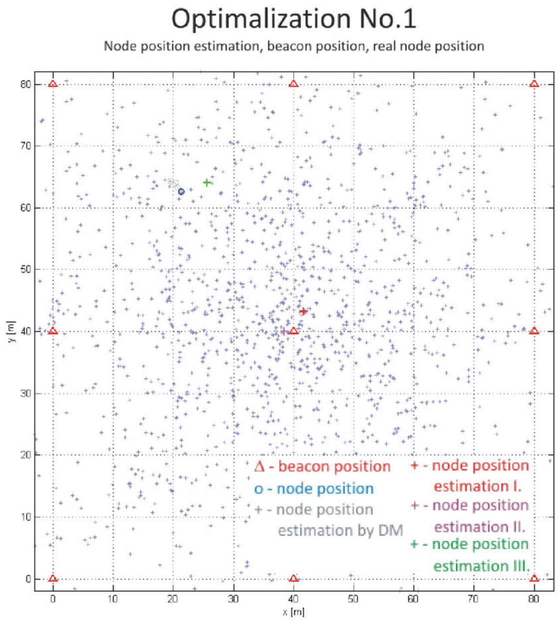

Fig. 5. In this case was beacons organised in grid and unknown mobile node was moved in four hops.

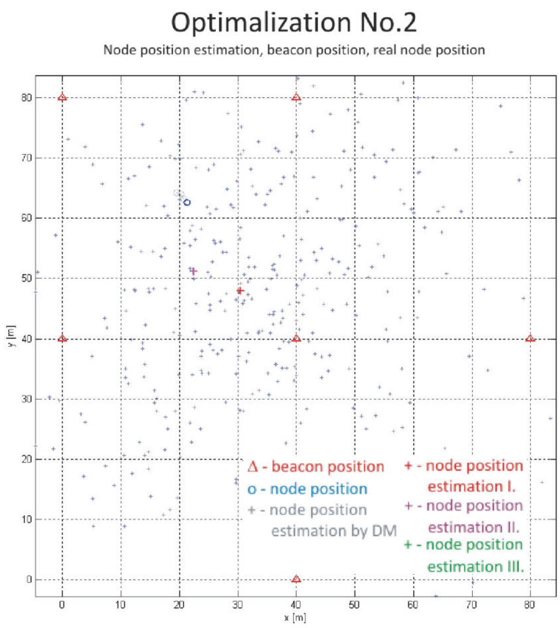

Fig. 6. On this figure is shown second step, where beacons were reduced from 9 to 6.

As well as from simulation results more beacons are not guarantee of more accurate node position estimation. In many cases it was just opposite. That is why our effort to find advisables three bacons, from which results position estimation will be the nearest to real. For this purpose we reduce gradually the number of beacons, to see from results of simulation how was changing estimation precision. Those we can see on results showed at Fig. 7 and 8.

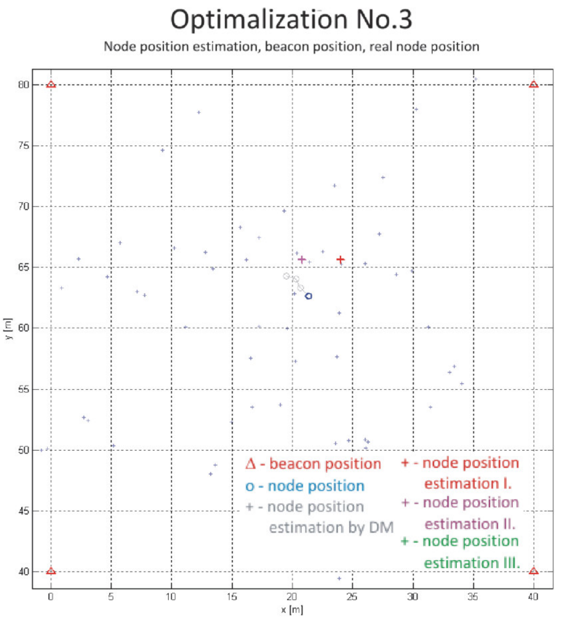

Fig. 7. On this figure is shown second step, where beacons were reduced from 6 to 4.

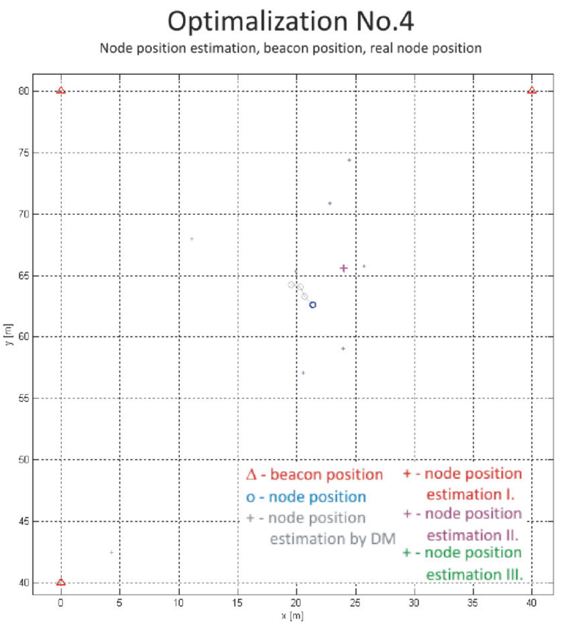

Fig. 8. On this figure is shown second step, where beacons were reduced from 4 to 3.

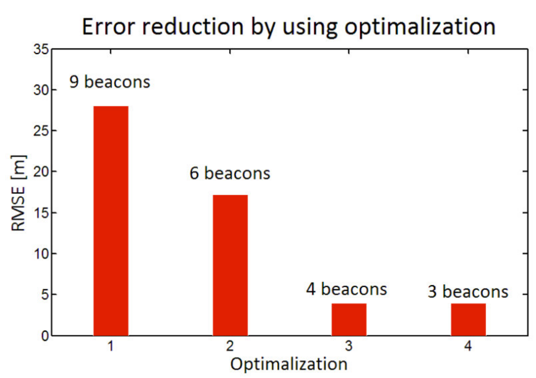

Fig. 9. On figure we can see error reduction by using optimalization (number of beacons) versus RMSE for estimation method I. (histogram max. from DM).

We can see RMSE (Root Mean Square Error) presentation of position estimation for first method (maximum of histogram from all DM) using optimalization by beacons reduction at Fig. 9.

4. CONCLUSION

Actual designed optimalization algorithm reduces beacon correctly to three closest to the unknowed node. However, algorithm needs to be tuned in (for reduction of errors) and modified nevertheless about next localization methods (as ToA, APIT, ...) as well as ways of dealing results interpretation (statistical - numerical methods) and calculating time reduction. The possibility of distributed calculation was offered to us for position measurement distributed for more nodes (in simulation for more PC´s).

Acknowledgement

This paper was prepared with the support of scientific-agency grant, which belongs to Ministry of education in Slovak republic VEGA-1/4065/07.

REFERENCES

[1] BASAGNI, S. – CONTI, M. – GIORDANO, S. – STOJMENOVIČ, I.: *Mobile Ad Hoc Networking*. John Wiley & Sons Ltd., 2004.

[2] ILYAS, M. – MAHGOUB, I.: *Handbook of Sensor Networks: Compact Wireless and Wired Sensing Systems.* CRC Press, 2005.

[3] WALKE, H. B. – MANGOLD, S. – BERCMANN, L.: *IEEE 802 Wireless Systems: Protocols, Multi-hop Mesh/Relaying, Performance and Spectrum Coexistence.* John Wiley & Sons Ltd., 2006.

[4] KÜPPER, A.: *Location-based Services*. John Wiley & Sons Ltd., 2005.

[5] DOBOŠ, Ľ., DÚHA, J., MARCHEVSKÝ, S., WIESER, V.: *Mobilné rádiové siete*. EDIS, 2002

[6] ZHU, J.: *Indoor/Outdoor Location of Cellular Handsets Based on Received Signal Strength.* Georgia, USA. 2006, pp. 123, A Thesis at School of Electrical and Computer Engineering, Georgia Institute of Technology. Advisor: Professor Gregory Durgin

[7] MELOUN, M. – MILITKÝ, J.: *Statistická analýza experimentálních dat*. Academia, 2004.