NS2 SIMULATOR CAPABILITIES IN NODES LOCALIZATION IN WIRELESS NETWORKS

Patrik Morávek
Doctoral Degree Programme (1), FEEC BUT
E-mail: moravek@phd.feec.vutbr.cz

Supervised by Dan Komosný
E-mail: komosny@feec.vutbr.cz

ABSTRACT

This paper deals with network node position estimation in a wireless environment, in other words, with wireless node localization. Several different methods of localization exist, and this paper summarizes them. Simulations generally are favourite tool in research and the ns2 simulator is one of the most widely used. That's why the focus of this paper is on the discussion of possibilities of the ns2 network simulator to simulate different localization methods and algorithms.

1. INTRODUCTION

The localization process is an important and necessary part in a lot of applications where it represents an auxiliary procedure in a network function or even a primary goal of the application. Localization as an auxiliary tool is also needed in techniques for localization-based efficient routing, data fusion and data mining with aspects of hierarchical data aggregation. The hierarchical aggregation itself represents advantageous function of all data networks because it saves precious bandwidth and in WSN also decreases crucial energy consumption [1].

Researchers in area of data networks generally rely on possibility of simulation as a part of their work. Simulations are important and sometimes the only possibility of their results or theoretical assumptions confirmation. Simulations are essential in case of proposed algorithms performance evaluation when a large-scale test-bed setting is not possible. Also, ensuring repeatability of tests across multiple test-beds is a difficult task in certain situations (e.g. wireless networks).

2. LOCALIZATION METHODS FOR WIRELESS NETWORKS

Localization techniques in wireless networks are categorized to groups of centralized techniques and decentralized techniques. The difference is obvious; the localization in the centralized schemes is controlled from one place of the network while in the decentralized ones, localization is performed in a distributed way in each node separately. Generally, localization is based on the type of information which nodes can obtain from the network. Each node has to be able to get useful information from performed measurement or received messages. The localization approaches are divided into hop-based (range-free) algorithms and range-aware algorithms. The hop-based ones express the distance between two nodes in number of hops. They do not consider any coordinate system. On the other hand, range-aware algorithms estimate distance and direction of two nodes from a measurement. Measurement techniques can be divided into three groups: Angle of arrival measurements, distance related measurements and received signal strength profiling techniques.

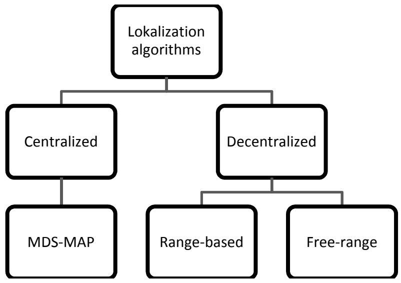

Fig. 1: Hierarchy of localization algorithms

2.1. AOA – ANGLE OF ARRIVAL MEASUREMENTS

AOA measurements can be further divided into antenna's amplitude response and antenna's phase response. The first category is based on the reception pattern of an antenna called beamform. The beamform is asymmetric with a noticeable preference in one direction. The measurement can be performed by receiver antenna rotation and detection of the maximum signal strength. The direction with the maximum signal strength is the supposed direction to the signal source. The trouble is when the signal is varying and the receiver cannot differentiate a received signal variation due to varying amplitude and due to anisotropy in the reception pattern. The solution can be in application of a second omnidirectional antenna which has a static beamform. Another approach is in utilization of two (or four) antennas with overlapping beamforms [2].
Phase interforometry technique [3] measures phase differences in the arrival of a wave front. It requires either large receiver antenna or an antenna array.

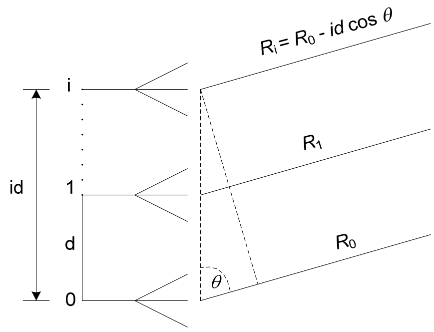

Fig. 2: An antenna array for phase interferometry

2.2. DISTANCE RELATED MEASUREMENTS

It is a category which includes time based related measurements, i.e. one-way propagation time measurements, round-trip propagation time measurements, time difference of arrival measurements, RSS measurements and others.
In the first technique, the distance between nodes is estimated from a propagation time measurement. There is a need of local time presented on each node and precise time synchronization. It means that nodes are supposed to be equipped with highly accurate clock and sophisticated synchronization mechanism. Therefore, second propagation time technique is more attractive for applications. Round-trip propagation uses the time interval between a transmitting of a signal and a reception of the signal in the reply from another node. There is no need of precise time synchronization because the time is measured on one device and the greatest error arises from signal processing on the second node.
TDOA (Time-difference-of-arrival) techniques utilize transmitter's signal measurement at multiple receivers with a known position to estimate coordinates of the transmitter. The TDOA between two receivers *i, j* is given by

$$TDOA \triangleq t_i - t_j = \frac{1}{c}\left(\|r_i - r_t\| - \|r_j - r_t\|\right), \qquad i \neq j, \qquad (1)$$

where t_i, t_j are the arrival times of signal from two transmitters at nodes i, j, c is the speed of light, r_i, r_j, r_t are locations and ||.|| is the Euclidean norm. Measuring of TDOA is quite difficult task; cross-correlation method is the one of the most widely used.[6]

Another technique of distance related measurements is dependent on a received signal strength indicator. It is a common technique of the distance estimation for its ease. It has no additional hardware requirements and a distance computation is based on the simple Friis equation [8]

$$P_r(d) = \frac{P_t G_t G_r \lambda^2}{(4\pi)^2 d^2}, \qquad (2)$$

where P_r (d) is the received power in dependence on the distance between transmitter and receiver, P_t is the transmitted power, G_t, G_r are transmitter's resp. receiver's antenna gain and λ is the wavelength of the transmitted signal in meters.

There are also other distance related techniques, such a lighthouse technique or measurement comparing speed of electromagnetic waves and sound.

2.3. RSS PROFILING MEASUREMENTS

Another category of localization techniques works with a form of a map constructed offline by a priori measurements or thanks to sniffing devices that are placed in a network at known locations. The map demonstrates a signal strength distribution in a coverage area.

3. DISCUSSION ON NS2 POTENTIAL FOR SIMULATION OF LOCALIZATION METHODS

For exploration and evaluation of localization methods in NS2 simulator it is needed to examine measurement possibilities of the simulator. Starting with range-based methods that are mostly dependent on a model of a physical layer, AOA is the first one from above described. AOA uses for its purposes a directional antenna with rotation and for better results also at least one omnidirectional static antenna. Thus, an option to select the antenna type and also more than one antenna per one node in the simulator is required.

In Tcl code is a type of an antenna defined in a node configuration as

```
$ns node-config –antType Antenna/OmniAntenna
```

Unfortunately, either change to directional antenna or adding extra antenna is not supported in NS2 simulator. This feature can be found in extension of NS2 called The Enhanced Network Simulator (TENS) with configuration option

```
$ns node-config -antType Antenna/OmniAntenna \  -numif   1
```

Measurement of TOA (Time of Arrival) is quite easy in the simulator because of the centralized time of the system for all nodes in the network. The time is provided by OS run on machine which runs the simulator. That is totally different situation in comparison with reality. There is a big and quite complex problem to ensure synchronized time in all nodes in a real test-bed. Fortunately, measurement of round-trip time can be much more realistic simulation with the same principle. Each node measures a difference between the time of transmitted packet and the time of received packet. The delay of processing of the packet can be found out from a real node performance and the resulting time set up in a delay procedure of the node.

```
Scheduler & s=Scheduler::instance();
s.schedule(target_,e,proct);
```

The RSSI measurement is well supported in NS2. The signal strength is measured at one node and the estimated distance of two nodes is computed from the formula (2) with known gain of transmitter's and receiver's antenna. It can be demonstrated in simulation with the following scenario. Let's assume two wireless nodes in certain coordinates at the beginning of the simulation. One of the nodes starts to transmit UDP and TCP packets through its wireless interface with given transmit power and antenna gain. We specify the propagation model as a FreeSpace Model and thresholds for carrier sense sensitivity and receive sensitivity. These thresholds define probability of successfully received packet. The OTcl configuration is following:

```
set opt(netif)        Phy/WirelessPhy
$opt(netif) set RXThresh_ 2.1352e-7          #receive sensitivity threshold
```

A separate C program is provided to compute the receiving threshold. If it is compiled, it can be subsequently used with:

```
threshold -m FreeSpace -r 0.95 30
```

which means that 95% packets is correctly received at the distance of 95m.

```
$opt(netif) set CXThresh_ 5.3352e-6          #carrier sense threshold
$opt(netif) set Gt_ 1            #transmitter antenna gain
$opt(netif) set Gr_ 1            #receiver antenna gain

$ns_ node-config     -energyModel EnergyModel \               #node configuration
                     -rxPower 0.281 \
                     -txPower 0.281 \
                     -phyType $opt(netif) \
                     -propType Propagation/FreeSpace
```

The nodes are approaching towards each other with the velocity of 0.5 m/s during the simulation that takes 60 s.The graph in Fig. 3 shows the bandwidth of wireless communication between these nodes for TCP and UDP connection.

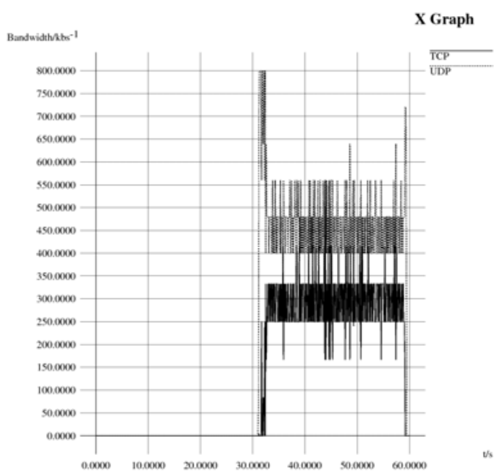

Fig. 3: The bandwidth of connection between the moving nodes

The communication starts at 31st s when the distance between nodes corresponds with received signal strength and the threshold RXThresh_. This condition is met at the distance of 31m.

4. CUNCLUSION AND FUTURE WORK

It can be concluded that the NS2 simulator supports simulations of different localization techniques with some limitations due to physical basis. There are a lot of possibilities and tools for individual needs of researchers in the NS2 simulator. The most important fact is that scientists can adapt all modules used in simulator to their thought. All layers of TCP/IP stack including physical one can be changed and even models which simulate transmission environment can be modified or created from the very beginning. That leads to the high level of independence from the designed framework of the simulator and during creating of own modules.

Further research will be focused on the selection of a localization method used in data gathering application in WSNs with respect to its accuracy and complexity. Data gathering is a principle of reduction of data volume that is transmitted from multiple users in the same time in data networks and a node localization is required for its effective function.

ACKNOWLEDGEMENT

This work was supported by the Czech Science Foundation - project No. 102/07/1012.

REFERENCES

[1] Šimek, M.; Komosný, D.; Burget, R.; Morávek, P.; Sá Silva, J.; Silva, R. Data Gathering Model for Wireless Sensor Networks Based on the Hierarchical Aggregation Algorithms for IP Networks. *International Journal of Computer Science and Network Security*. 2008. 8(11). p.200-208. ISSN 1738-7906.

[2] Guoqiang Mao, Barıs_ Fidan, Brian D.O. Anderson, Computer Networks: The International Journal of Computer and Telecommunications Networking Volume 51 , Issue 10 (July 2007) Pages 2529-2553 Year of Publication: 2007 ISSN:1389-1286

[3] T. Rappaport, J. Reed, B. Woerner, Position location using wireless communications on highways of the future, IEEE Communications Magazine 34 (10) (1996) 33–41.

[4] M. Takai, J. Martin, and R. Bagrodia. Effects of wireless physical layer modeling in mobile ad hoc networks. In 2001 ACM International Symposium on Mobile Ad Hoc Networking and Computing (MobiHoc 2001), pages 87–94, October 2001

[5] N. Patwari, A. Hero, M. Perkins, N. Correal, R. O'Dea, Relative location estimation in wireless sensor networks, IEEE Transactions on Signal Processing 51 (8) (2003) 2137–2148.

[6] W.A. Gardner, C.K. Chen, Signal-selective time-differenceof-arrival estimation for passive location of man-made signal sources in highly corruptive environments. I. Theory and method, IEEE Transactions on Signal Processing 40 (5) (1992) 1168–1184.

[7] T.S. Rappaport, Wireless Communications: Principles and Practice, second ed., Prentice Hall PTR, 2001.