

NetLogo – an alternative way of simulating mobile ad hoc networks

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Abstract—The characteristics of mobile ad hoc network result in necessity of using the simulation for verification of newly proposed concepts in mobile ad hoc networks. Traditional network simulators are oriented towards low level simulation, which leads to various difficulties when these simulators are used for simulation of high level aspects of mobile ad hoc networks. This paper proposes the use of multi-agent programming language NetLogo for simulating high level aspects of mobile ad hoc networks. Applicability of this tool is demonstrated by simulating and evaluating security criteria of various public key infrastructure approaches in mobile ad hoc network in NetLogo.

Keywords- MANET; simulation; Netlogo; ad hoc network

I. INTRODUCTION

Mobile ad hoc network is unique kind of computer network. The main characteristic of this kind of network is mobility of individual devices, which communicate in this network. This fact leads to absence of fixed topology and infrastructure in mobile ad hoc network. Every device working in mobile ad hoc network has to be capable of acting as router and therefore must be able to forward communication for other devices in network. All devices communicate via wireless links with each other.

The concept of mobile ad hoc network dates back to the seventies of last century, when potential of mobile ad hoc networks for military domain was identified. Military domain was for long time the only intended domain for deployment of mobile ad hoc networks. However, the technological advancement in recent years along with arrival of accessible portable devices with capability to communicate via wireless technology extended the potential deployment of mobile ad hoc networks also for non-combatant domain. This alteration of mobile ad hoc network applicability resulted in enormous interest of research and academic community in this kind of networks. The research was originally oriented on design and implementation of routing protocols from mobile ad hoc networks. Nowadays, the research is more and more oriented on security of mobile ad hoc networks.

Carrying out real world experiments on mobile ad hoc networks is very difficult because actual state of mobile ad hoc network depends upon substantial quantity of various parameters such as number of nodes, area of mobile ad hoc

network or mobility of nodes. Large variability of parameters as well as character of individual parameters of mobile ad hoc network leads to additional difficulties, when trying to use real world mobile ad hoc network for verification of newly proposed concepts in mobile ad hoc networks. This fact results in necessity of using the simulation of mobile ad hoc networks in academic research. Traditional tools for simulating mobile ad hoc networks are OPNET, GloMoSim/QualNet, NS-2, NS-3 and OMNeT++ [1]. Traditional network simulators were initially used for simulating classic networks with fixed topology and infrastructure. They are primarily utilized for design and attestation of routing protocols for mobile ad hoc networks. Low level orientation of traditional network simulator leads to various difficulties when these simulators are used for simulation of high level aspects of mobile ad hoc networks.

We propose the use of NetLogo for simulating high level aspects of mobile ad hoc networks. NetLogo is multi-agent programming language based on Logo programming language and integrated modelling environment. It is particularly well suited for modelling complex systems developing over time. NetLogo models are used in variety of domains such as economics, biology, physics, chemistry, psychology, system dynamics and many other natural and social sciences. We have identified and demonstrated appropriateness of NetLogo also for modelling and simulating high level aspects of mobile ad hoc networks. Specifically we have used NetLogo for simulating and evaluating security criteria of various public key infrastructure approaches in mobile ad hoc network.

This paper is divided into five sections. Section 2 introduces several studies related to segments of our project. Section 3 contains presentation of NetLogo programming language along with arguments why should be used for mobile ad hoc networks modelling and simulation. Section 4 describes our design and implementation of mobile ad hoc network model in NetLogo and design of public key infrastructure approaches models in NetLogo and finally section 5 concludes the paper and presents achieved results.

II. RELATED WORK

The idea of using multi-agent programming language for modelling and simulating mobile ad hoc networks is inspired

by work presented in [2]. Author of this paper pinpoints shortcomings of traditional network simulators, when used for simulating complex computer networks such as pervasive computing, large scale peer-to-peer networks involving considerable environment and human/animal/habitat interaction. Author proposes use of NetLogo for modelling and simulating complex computer networks, describes NetLogo programming language and highlights features of NetLogo which provide main advantages over traditional networks simulators. Author has created four elementary models of complex computer networks in order to demonstrate effectiveness of NetLogo.

Creating models of mobile ad hoc networks and challenges associated with it are well known and extensively described in scientific literature. To create computer model of mobile ad hoc network with all details of current state of this network is almost impossible and generally also undesirable. Models of real world are therefore created with certain level of granularity. Paper [3] demonstrated that poorly selected level of granularity, which neglects some important details, has very serious impact on accuracy of results from simulation. Paper [3] therefore recommends independently analysing, designing and optimising needed level of mobile ad hoc network model granularity according to intention of created model and according to results which model should provide.

Main critical factor affecting the results of mobile ad hoc network simulation is mobility model of nodes. Mobility model of nodes, as defined in [4], "is a set of rules used to generate trajectories for mobile entities." This paper demonstrates critical impact of chosen model of mobility on results obtained from simulation of mobile ad hoc network. Badly chosen mobility model of nodes leads to incorrect simulation results. Standard mobility models are stochastic models of mobility. However in papers [5][6] is harmful impact of stochastic mobility models to overall simulation analysed and demonstrated. Shift to more realistic mobility models of nodes in mobile ad hoc networks is therefore currently in progress. More realistic mobility models are designed and presented in paper [7].

III. NETLOGO

NetLogo is multi-agent programming language based on Logo programming language. In its current version, NetLogo is distributed as open-source. NetLogo was designed and developed from the grounds up for modelling and simulating complex systems developing over time. NetLogo was used to model and simulate various complex systems in variety of domains such as economics, biology, physics, chemistry, psychology, system dynamics and many other natural and social sciences.

Agent-based simulation assumes certain level of intelligence of each network node on local level. This is especially useful in distributed environment with large-scale complex interacting entities such as mobile ad hoc networks [2]. Among main advantages of NetLogo over traditional simulators that determine use of NetLogo in domain of mobile ad hoc networks are direct addressability of individual nodes

in network and ease of implementation and evaluation of self-organization. Another advantage is possibility of effective and simple modelling of interaction protocols among individual agents, which is especially suitable for domain of mobile ad hoc networks. Appropriateness of NetLogo for mobile ad hoc networks modelling is also determined by wide range of input parameters that can be defined in creation of model. Integrated modelling environment in NetLogo provides excellent base for automatic generation of statistics about simulated variables. Interactive interference with currently simulating model without need for reprogramming existing model is another advantage of NetLogo.

Applicability of NetLogo for modelling and simulating mobile ad hoc networks was up to now in academic environment demonstrated only in theory or only on very elementary models in [2]. Our research therefore aims to demonstrate applicability of NetLogo for verification of complex concepts in mobile ad hoc networks. One of such complex concepts is public key infrastructure approach in mobile ad hoc networks. By simulating and evaluating security criteria of various public key infrastructure approaches in mobile ad hoc network using NetLogo, we demonstrate NetLogo suitability for modelling and simulating high level aspects of mobile ad hoc networks.

IV. MODELLING IN NETLOGO

Simulation of mobile ad hoc networks in NetLogo is new paradigm in mobile ad hoc simulation. First thing when trying to simulate high level aspects of mobile ad hoc network is creation of realistic mobile ad hoc network model in NetLogo. After successful implementation of realistic mobile ad hoc network model that can be used for simulating higher aspects of mobile ad hoc networks we need to implement model of particular simulated aspect. In our case, we need to implement models of different public key infrastructure approaches that can be simulated on top of our implemented model of mobile ad hoc network.

A. Model of mobile ad hoc network in NetLogo

As shown in paper [3], first step when creating model of mobile ad hoc network is analysing, designing and optimising needed granularity level of mobile ad hoc network model. Because we are trying to simulate and evaluate higher application level aspects of mobile ad hoc network such as applied public key infrastructure approach, we can operate with several approximations and neglect some low level aspects of mobile ad hoc network without negatively disturbing correctness of simulation results.

One low level aspect of mobile ad hoc network we can safely neglect is used routing protocol. This can be done because all public key infrastructure approaches operate with precondition that mobile ad hoc network uses one of already known and functional routing protocol and therefore all devices in mobile ad hoc network can transparently communicate with each other. This allows us to completely skip implementation of routing protocol and work with simple postulate that if neighbouring node is in communication range of transmitting node, the transmitting node can freely

communicate also with all nodes that are in communication range of neighbouring node. This postulate will almost never be true in real world mobile ad hoc networks, especially, if reactive routing protocol is used for routing, however since all considered public key approaches used same assumption, the correctness of simulation results will not be disturbed. Here can be seen one of the main advantages of NetLogo over traditional mobile ad hoc networks simulators – total freedom when choosing desired granularity of model. This model thus uses free path loss model of radio wave propagation. Path loss is power reduction of an electromagnetic signal upon the distance. The free path loss is the theoretical path loss of a signal whose propagation does not suffer from the presence of any obstacle [8]. Free path loss model of radio wave propagation can therefore be defined by one input parameter in our implemented NetLogo mobile ad hoc network model – *communication range of nodes*.

As already mentioned in related work, mobility model of nodes has critical impact on results obtained from simulation of mobile ad hoc network. NetLogo simulator allows detailed specification of individual nodes movement and therefore implementation of various mobility models is trivial matter. Because of this we were able to implement two stochastic mobility models – Random Walk Model and Random Waypoint Model - along with two more realistic mobility models – Nomadic Community Mobility Model and Pursue Mobility Model – with ease and in little time. All mentioned models are thoroughly described in [8]. *Choice of desired mobility model* is another input parameter of our implemented model of mobile ad hoc network.

Another critical factor when simulating mobile ad hoc network is character of simulated area, where simulated mobile ad hoc network operates. Simulated area is usually geographically bounded. Presence of these bounds leads to several topological specifics like non-uniform distribution of nodes in simulated area. Boundless Simulation Area Mobility Model tries to eliminate these unwanted phenomena. Node which reaches border of simulation area, instead of bouncing of this border, will appear on opposite simulation area border. NetLogo allows choosing character of simulated area in simulation properties ergo character of simulated area is another input parameter of our mobile ad hoc network model implementation.

In addition to described input parameters, our model also accepts following input parameters – *number of nodes* that allows defining overall amount of simulated nodes and *size of simulated area* that defines extent of simulated area.

B. Models of public key infrastructure approaches

We decided to simulate, evaluate and compare security criteria of various different public key infrastructure approaches. We chose following public key infrastructure approaches for simulating – *Secure and efficient key management* described in [9], *Self-securing mobile ad hoc network* described in [10], *Self-organized public-key management* described in [11], *Trust- and clustering-based authentication* described in [12] and *Cluster-based security architecture* described in [13].

We have created one model for each chosen public key infrastructure approach. This task would be enormously difficult to complete when using traditional simulators. In NetLogo is this task much easier, because NetLogo has capability of creating and simulating complex interaction algorithms that are easily understandable from the human perspective. This allows creating implementations of individual approaches according to reference implementations described in individual papers.

In order to actually evaluate and compare various public key infrastructure approaches we had to determine several output parameters. By monitoring these output parameters we are able to collect enough data to evaluate and compare simulated public key infrastructure approaches. We have specified following output parameters that all implemented models of public key infrastructure approaches must provide – *creation, existence and availability of trustworthy certificate authority, time until creation of certificate authority, availability of authentication service and effectiveness of communication*.

To demonstrate effectiveness of creating new models in NetLogo, we present our commented implementation of Random Walk mobility model in NetLogo programming language.

```
globals [ ; global variables
  min_speed ; minimum speed of movement
  max_speed ; maximum speed of movement
]
to move_random_walk
  ask turtles [
    rt random 360; set random heading
    forward random_float min_speed max_speed
    ;advance with random speed
  ]
end
```

Typical graphical user interface when simulating created mobile ad hoc network model in NetLogo is presented in Fig. 1. On the left side, we can see some of input parameters of implemented model along with some output parameters from the simulation of model. On the right side, we can clearly see simulated mobile ad hoc network also with visualization of simulated network.

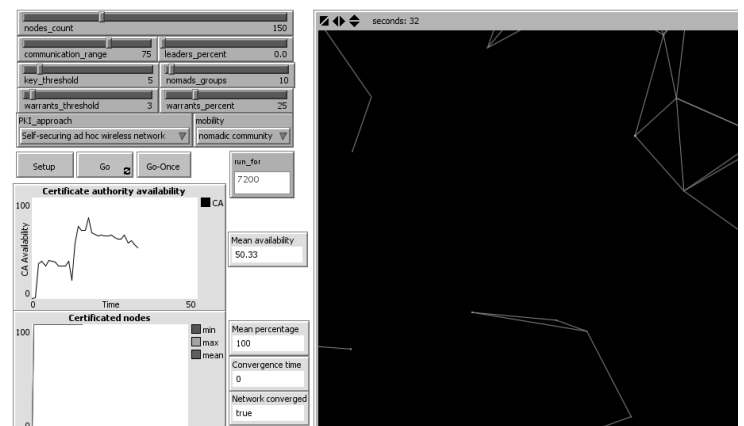


Figure 1. Typical user interface of NetLogo

V. CONCLUSIONS AND FURTHER WORK

We have analysed programming language NetLogo and identified several features and advantages of NetLogo over traditional network simulators that predetermines application NetLogo for modelling and simulating mobile ad hoc networks especially simulating higher aspects of mobile ad hoc networks. We have designed and implemented realistic model of mobile ad hoc network in NetLogo and therefore we have demonstrated applicability of NetLogo in mobile ad hoc network modelling and simulation. We have also analysed and designed models of several public key infrastructure approaches in mobile ad hoc network in such way, that we can evaluate and compare security criteria of these approaches. We have also implemented models of public key infrastructure approaches in mobile ad hoc networks in NetLogo using underlying implemented mobile ad hoc network model.

Future work is finer refining of implemented models of public key infrastructure approaches, simulation of these models and finally evaluation and comparison of different public key infrastructures in order to demonstrate NetLogo applicability for modelling and simulating high level aspects of mobile ad hoc networks.

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