

A Visualisation Tool for Ad Hoc Networks ViTAN

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Abstract—The Visualization Tool for Ad Hoc Networks — ViTAN is a tool for visualizing the connectivities and link qualities (capacities) between the terminals in wireless ad hoc networks. The ViTAN tool takes the location of the wireless terminals (specified by Cartesian coordinates) and the link qualities between the terminals as input. The tool produces a visualization of the graph of the terminals' connectivities in the `fig` format, which in turn can be converted to any common graphic format. ViTAN does not evaluate the connectivities and link qualities in ad hoc networks. Instead, ViTAN takes the link qualities obtained from other tools, simulations, or analytical evaluations as input and graphically visualizes these link qualities and the resulting connectivities in the network. For the information exchange between ViTAN and other tools a simple interface is provided. By this separation ViTAN can be utilized for a wide range of applications, focusing on its strengths in visualization. ViTAN facilitates the visual study of complex ad hoc networks by depicting higher link qualities with thicker edges and in darker gray shades. In addition, ViTAN draws the edges at different depth levels of the `fig` format depending on the corresponding link quality. This feature enables the selective display and visual study of the connectivities provided by links with a specific quality range. ViTAN is an open source project and therefore the source code and a detailed documentation is publicly available. We employ ViTAN to examine a CDMA and an IEEE802.11a based ad hoc network.

Keywords—visualization, ad hoc networks, perl

I. MOTIVATION

Ad hoc¹ enabled wireless terminals can dynamically form a network, wherever the network infrastructure is missing, incomplete, or inadequate. Due to the potential ease of deployment, there are many interesting application scenarios for ad hoc networks. Example scenarios include disaster management, military operations, vehicle communication, or in general scenarios where a group of people wish to communicate with each other [1]. In ad hoc networks communication is possible in a *point-to-point* fashion between wireless terminals. If the coverage of two terminals is too small to reach each other, the terminals communicate by *hopping* over neighboring terminals. Multi-hopping enables two distant terminals to communicate with each other and has also the potential to save energy. For these reasons, ad hoc networks have attracted a great deal of interest from the network research community.

In the study of ad hoc wireless networks researchers often face the problem of analyzing complex networks formed by nodes (terminals) that are placed in a wide variety of topologies. The placement of the nodes and their respective wireless transmission and reception capabilities typically rise to a complex network graph consisting of nodes interconnected by wireless links (edges) of heterogeneous quality (capacity). A visual representation of this network graph is often very helpful in evaluating the performance of a network protocol or mechanism for ad hoc networks. We were looking for a simple yet effective visualization tool for the network graph and came to realize that there was no such tool available. We were thus motivated to develop a tool that takes the terminal (node) locations and the qualities (capacities) of the links (edges) interconnecting the nodes as input and generates a visual representation of the network graph. We chose the `fig` (often

¹We note that (i) the terms *ad hoc* and *multi hop* are used interchangeably in this paper, and (ii) these terms may have slightly different definitions in the literature.

referred to as `xfig`) graphics format for our ViTAN tool, since this format is widely used. The source code of our ViTAN tool is available for free from a number of web sites [2], [3], [4]. In Figure 1 the ViTAN output is given for an IEEE802.11a multi-hop network topology with fixed Internet access. Later we will explain the plot more in detail.

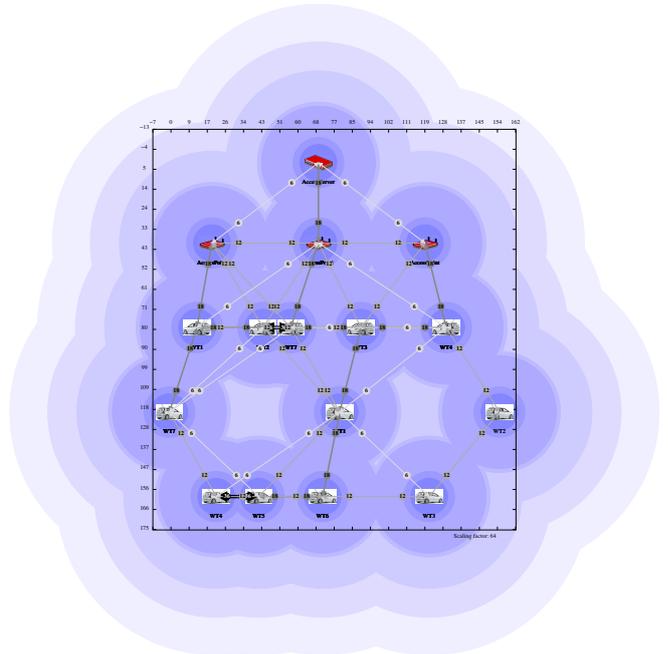


Fig. 1. IEEE802.11a multi-hop network topology with fixed Internet access.

II. THE ViTAN TOOL

The goal of our work was to develop a very simple, but effective tool to illustrate the network graph of ad hoc networks. Moreover, we wanted the tool to be scriptable and thus usable by other programs. That meant to have a simple interface between ViTAN and other simulation tools or programs. We have chosen the perl language to write the ViTAN tool to make sure that other researchers can easily modify the program to their needs. The source code of our ViTAN tool is available for free from a number of web sites [2], [3], [4]. The downloaded files has only to be untared. The ViTAN tool *v1.1* as specified in [5] is invoked from the command line with following parameters:

```
vitan.pl ifile ofile [flag1 [flag2 [minX maxX minY maxY]]]
```

The input file for ViTAN contains all important information to generate and illustrate the ad hoc network. Assuming that we have J wireless terminals, each wireless terminal j , $j = 1, \dots, J$, is identified by its unique Cartesian coordinates (x_j, y_j) . Furthermore each wireless terminal has a name and a transmission range. In addition, the link quality LQ to each of the other wireless

terminals has to be specified. A valid row entry of the inputfile looks as follows:

```
XCOOR YCOOR NAME RANGE TERMINALPRESENTATION
LQ1 LQ2 ... LQJ
```

A possible ViTAN input file may look like this:

```
1000 1000 Enno 2237 soldier 0 8 0 0 0 0
3000 2000 Patrick 2237 soldier 2 0 8 0 0 0
5000 3000 Gaby 2237 smart 0 4 0 5 0 0
7000 4000 Rolf 2237 smart 0 0 5 0 4 0
9000 5000 Gimpel 2237 pda 0 0 0 8 0 2
11000 6000 Stefan 2237 pda 0 0 0 0 8 0
```

The unit of the length for XCOOR, YCOOR, and RANGE is one centimeter [cm]. In case max_X and max_Y are not specified, ViTAN sets these values to the largest x_j and y_j values plus some offset value. A valid entry for a name is any ASCII word. For the link quality any integer value between 1 and 255 is valid. The outputfile is in the fig format [6] which can be displayed with the xfig [7] tool. Several switches are used to enable or disable the features. In the following we explain the usage of the parameters and switches in detail.

A valid entry for NAME, as given in our example, is any ASCII word. The TERMINALREPRESENTATION gives the name of the gif figure without the gif suffix, which should represent the node. Note, the ViTAN package comes along with a set of gif figures. The figures are stored in the sub-directory named *terminalpics*. Any picture can be stored in the sub-directory and used with the ViTAN tool. An open problem is the automatic scaling of the gif figures. For this purpose perl offers the IMAGE package. Because the IMAGE package does not run on each platform, the size is set statically. This might result in a disproportionate representation of the terminal. This issue will be fixed in one of the next versions. If flag1 is set to 1 in the program call, then the TERMINALREPRESENTATION is ignored. An example of different representation of terminals is given in Figure 1. In contrast to the first ViTAN version 1.0, different figures per wireless node and auto scaling for a better illustration is introduced. In the following we explain the flags and parameters more in detail.

flag1: Flag1 has two valid values [0,1]. In case the flag is set to 0 the terminals are represented by a graphic named *terminal.gif*, otherwise the terminals are represented by a red point. Note, any gif file can be used for the illustration of a terminal. It might be necessary to adjust the size in the ViTAN tool (lines 154 and 155 of the Perl source code given in [8]). As an example for vehicle communication, Figure 1 shows multiple cars using the IEEE802.11a technology. In the following the resulting bit rates between the vehicles are explained in more detail.

flag2: Flag2 has two valid values [0,1]. In case the flag is set to 0 the figure is in the landscape format, otherwise the portrait format is used.

maxX: max_X specifies the maximum value of the x coordinate. In case this value is not specified, the ViTAN tool itself sets this value taking the highest XCOOR value plus some offset.

maxY: max_Y specifies the maximum value of the y coordinate. In case this value is not specified the ViTAN tool itself sets this value taking the highest YCOOR value plus some offset.

minX: min_X specifies the minimum value of the x coordinate. In case this value is not specified, the ViTAN tool itself sets this value taking the lowest XCOOR value minus some offset.

minY: min_Y specifies the minimum value of the y coordinate. In case this value is not specified the ViTAN tool itself sets this value taking the lowest YCOOR value minus some offset.

As already mentioned before the output of the ViTAN tool is a XFIG file. Using the XFIG program the ViTAN output can be displayed and modified. But there is a further advantage

Tab. 1. Depth Level of the ViTAN XFIG output.

| XFIG element | depth level |
|---------------------------|---------------------|
| quality label on edge | i.e., 1, 2, ..., 8 |
| edge | 600 + quality level |
| terminal (node) | 700 |
| names/ID | 701 |
| bounding box with numbers | 800 |
| coverage area | 900 |

using the XFIG tool. The xfig tool version 3.2 [7] can display elements of a given figure as a function of their depth level. This is very helpful to illustrate specific parts of the figure and increase the visibility of the conductivities, as we will illustrate with one example. By switching off (i.e., hiding) certain depth levels we can focus on the remaining parts of the figure. Any xfig element can also be deleted manually, but by grouping elements the visualization is improved. ViTAN assigns depth levels automatically. The terminals, the bounding box and the coverage area have static depth levels, other elements' depth depend on the link quality. Table 1 gives all depth levels of the xfig output.

Two example outputs of the ViTAN tool are given in Figure 2 and Figure 1. In Figure 2 six wireless terminals are forming the chain topology in a CDMA based network. Note that due to the interference limitation of CDMA, the link quality is non symmetrically, e.g., terminal Enno hears terminal Patrick with better quality than vice versa. This example is taken from [9]. For all terminals the transmission range is depicted. The area is 70 m per 120 m. On the x axis and the y axis the range in meters is given.

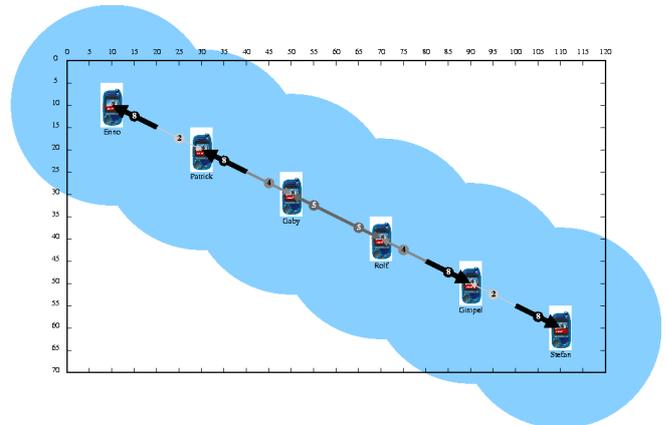


Fig. 2. A simple chain configuration of six wireless terminals with graphical representation of the terminals.

Figure 3 shows the screen-shot of the xfig tool with the CDMA based chain network (illustrated in Figure 2) using the depth capabilities. In Figure 3 the depth levels 2, 5, and 900 are hidden, i.e., the coverage areas and the links with quality levels 2 and 5 are not shown.

The color of the edges is a function of the link quality. Higher link quality as given by larger values in the connectivity matrix is depicted by darker gray colors, while lower quality levels are depicted with lighter gray colors. The colors are generated automatically by ViTAN because these gray scaled colors are not part of the xfig tool which offers only a limited set of colors. Furthermore, gray colored graphs are more useful on a printer's output. In addition, the width of the edges is a function of the link quality, with thicker edges representing higher link quality. For better illustration only width values between 1 and 8 are valid. In case higher quality levels are chosen in the connectivity matrix

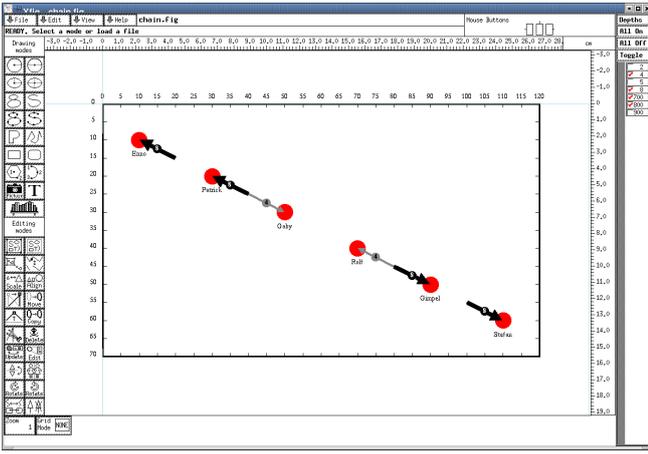


Fig. 3. A screen-shot of the xfig tool using the depth levels for the chain scenario.

the values for the width are adjusted proportionally.

After generating the fig file any popular graphic format can be obtained by using the fig2dev program. The fig2dev program is part of nearly every Linux distribution and sometimes comes along with the xfig tool [7]. All common graphic formats such as gif, jpeg, png, ppm, ps, eps, and pdf are supported. For a full list of all supported graphic formats please refer to the fig2dev man pages. To convert a XFIG file into any other format simply evoke:

```
fig2dev -L GRAPHICFORMAT file.fig output
```

The ViTAN tool comes with a short shell script to generate pdf files for all example topologies. By simply evoking the script export the files in the graphic formats fig, pdf, and png are generated.

After this short introduction to the ViTAN tool (see [8] for more detail), the following section outlines the strengths of this tool by means of two different scenarios.

III. TWO EXAMPLES

In this section we examine two different ad hoc network examples with the ViTAN tool. The first example is a CDMA based ad hoc network. We examine the impact of an interference based power control entity for different topologies. We demonstrate that ViTAN is able to illustrate the asymmetric link qualities, which are characteristic for CDMA based ad hoc networks. The second example is an IEEE802.11a based ad hoc network. A key feature of IEEE802.11a is the multi modulation capability, i.e., the data rates depend on the link quality between sender and receiver. With the ViTAN tool we illustrate these data rates between multiple wireless terminals.

A. CDMA based Ad Hoc Network

In [9] we introduced an interference based power control entity for a CDMA ad hoc network with pseudo-noise spreading sequences. The bit error probability for communication between CDMA sender and receiver depends on the received power of the desired signal and the interference power caused by the undesired signals,

$$P_{biterror} = Q \left(\sqrt{\frac{2 \cdot P_r(k) \cdot G}{\sum_{j=1 \dots J, j \neq i} P_r(j)}} \right), \quad (1)$$

where $P_r(k)$ is the received power and G the spreading gain of terminal k . In uncoordinated systems, wireless nodes in the center

of a given topology suffer from more and stronger interferences and at the same time have to transmit more data than nodes at the edge of a given cluster. Nodes in the center have to transmit more data as they are relaying transmissions from nodes at the edge in multi hop fashion. The design goal for our power control unit was to enable higher bandwidth for such center nodes by reducing the interference coming from wireless nodes at the border of the cluster. In Figure 4 an ad hoc network with the bridge topology is depicted. In this example nodes Zoe and Oliver enable communication between the two sub groups G_1 and G_2 by means of multi hopping. G_1 is the group composed of Enno, Gaby, Carsten, and Rolf and G_2 is formed by Frank, Robill, Gimpel, and Andreas. The values on top of the arrows represent the link quality: higher values indicate higher quality and vice versa. Eight different quality levels were chosen to represent the link quality. Note, in a CDMA system the link quality is not symmetrical, because the interference levels differ between sender and receiver.

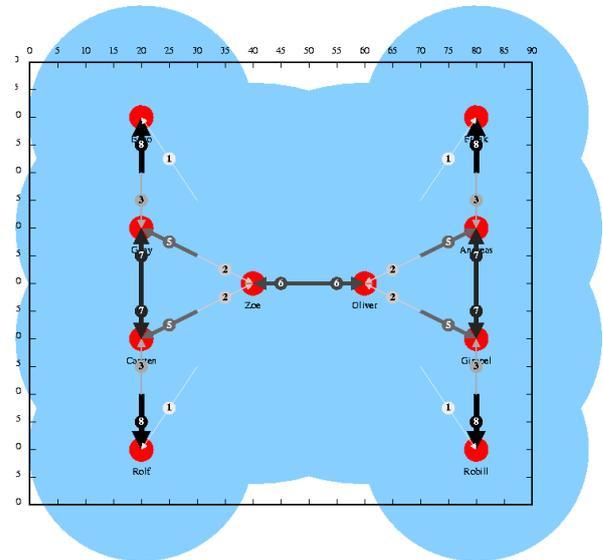


Fig. 4. CDMA based ad hoc network with bridge topology.

B. IEEE802.11a based Ad Hoc Network

At the FUTURE group of the department of Engineering at the University of Ferrara a link-level simulator for 802.11a was developed using MATLAB [10]. The simulator allows for the investigation of the performance of IEEE802.11a enabled wireless nodes in a two dimensional area. The wireless link model takes path loss, correlated shadowing, and Jake's multi-path fading into consideration. In contrast to IEEE802.11b, the new IEEE802.11a is based on OFDM with link adaptation. Therefore the data rate used between two wireless nodes is highly correlated to the link quality.

An exemplary topology for a multi user scenario is given in Figure 5. 22 wireless terminals are distributed randomly over a 110 m by 110 m area. Each wireless terminal is identified by an ASCII word. Using IEEE802.11a technology, terminals are connecting to each other with different data rates. In Figure 5 wireless terminals are presented that are sending with a data rate of exactly 12 Mbit/s. The coverage area was not illustrated to increase visibility. The plot were generated with the ViTAN tool [8] using the depth capability. This feature significantly increases the visibility of the plots. A single plot with all connections would be very confusing.

Tab. 2. Download for the ViTAN tool.

| | |
|---------|---|
| Germany | http://www.acticom.de/vitan.html |
| USA | http://www.eas.asu.edu/~mre/vitan |
| Italy | http://www-tlc.ing.unife.it/tools/vitan |

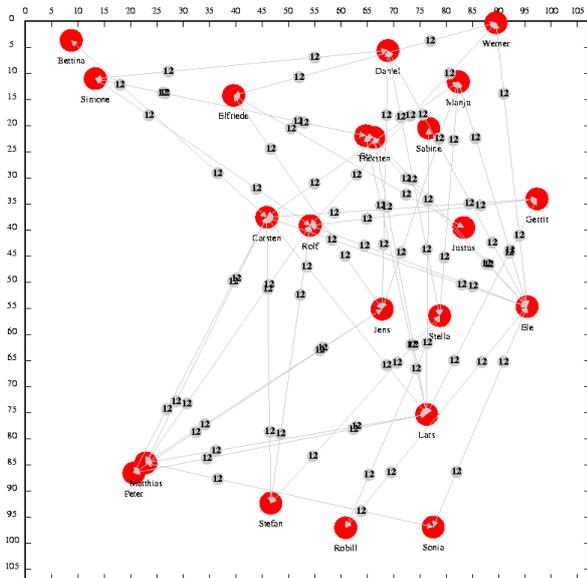


Fig. 5. Ad hoc network with all connections at 12Mbit/s.

IV. DOWNLOAD INFORMATION

The ViTAN tool and related examples can be downloaded from three different web pages given in Table 2. As mentioned before the source code of the ViTAN tool is open source and can be changed by each researcher for its own needs.

V. CONCLUSION

We have introduced ViTAN, a Visualization Tool for Ad hoc Networks. ViTAN illustrates the link qualities and conductivities in ad hoc networks. ViTAN allows for easy scripting and can thus be used in conjunction with other programs in a straightforward manner. ViTAN produces illustrations in the `fig` graphics format, which can be easily converted to any other common format. ViTAN enables the visual study of ad hoc networks by drawing links in different gray shades and widths, and at different depth levels of the `fig` graphics format. The depth drawing feature allows the viewer to visualize specific link quality levels in isolation and is therefore particularly useful for the study of highly complex networks. We have illustrated the features of ViTAN by applying it to two ad hoc network examples, a CDMA based network and an IEEE802.11a based network.

VI. OUTLOOK

First extensions to the ViTAN have been made. As given in Figure 6 the energy consumption for sensors can be easily generated in a 3D fashion changing the ViTAN source code. In this specific scenario sensors, which are far away from the access point transmit with more energy. Larger energy consumption is represented by the height of the cylinders and a red color, while small energy consumption is represented by small cylinders with a green color. In Figure 7 the sensor topology is given. Also this figure is generated with small changes to the ViTAN source code. A next version of ViTAN is on the way. Furthermore an extension for IEEE802.11a is under testing. A first result is given in Figure 1 illustrating a multi-hop network. The possible data rates of an IEEE802.11a wireless terminal are given for each wireless node.

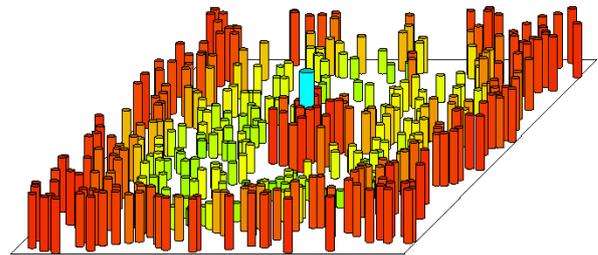


Fig. 6. Energy consumption in a sensor network.

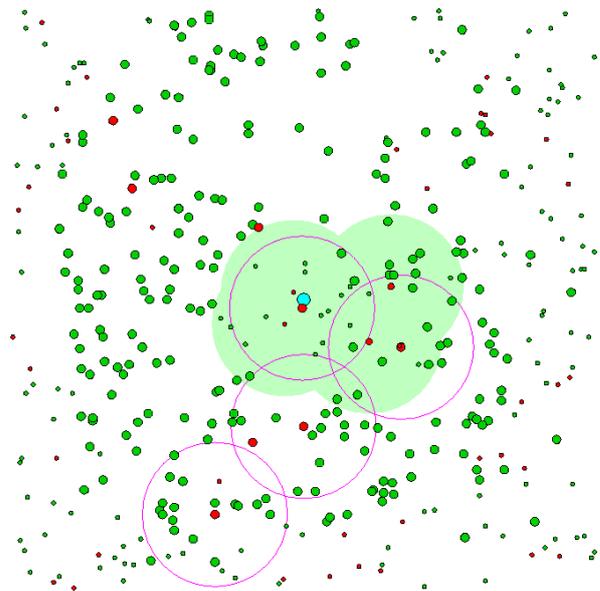


Fig. 7. Sensor network topology.

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