Building a Wireless Community Network in The Netherlands

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Abstract

With the development of low cost hardware for wireless networking based on IEEE 802.11b, wireless networks are an emerging technology. Using these wireless techniques outdoors it is possible to build a community network not dependent on any provider. In the Netherlands such a network is being set up in and around Leiden. Using low cost network boards, home-built antennas and open source software the volunteers of the Wireless Leiden Foudation are able to lay-out an infrastructure for the inhabitants of Leiden at a very low cost. All kinds of applications (profit and non-profit) are using this entirely wireless network.

1 Introduction

Current computer networks generally rely on a permanent, fixed and largely wired infrastructure which is owned and often operated by large entities such as telecom operators. A relatively new and emerging technology is wireless ethernet or wireless networking using the IEEE 802.11 standard. This standard encompasses the lower layers of the OSI model for transport of data as ethernet frames using a spread spectrum based radio link.

This technology opens the possibility of building a network without having the problems associated with, and the cost of putting some sort of physical transmission medium in the ground. Instead, antennas can be used to send and receive the data using radio waves through free air.

Because of the relative simplicity of the currently available commodity hardware that uses 802.11 technology it is relatively easy to build a local wireless community network in a town. Using this network people can share resources among each other. Examples are sharing sound or video files with the local musea or having data provided by the local government on-line. Furthermore, the network can connect to the Internet providing a low cost way of crossing the last mile to the user at high bandwidth.

In Leiden, The Netherlands, a foundation is established by a number of knowlegeable volunteers with the intention to build a network operated and owned by a community of users, not by big entities such as telcos or Internet Service Providers. This essentially "free" network infrastructure, can be used by anyone present in the service area for running his or her own application. On the client platform only an industry standard IEEE 802.11 interface and a problably asmall antenna is needed. Usage of the infrastructure is not "another monthly bill", but will be free, after a one time up-front investment in equipment.

2 Method

2.1 Introduction

The wireless community network built has a number of requirements to be sucessfull. First of all it has to be as “open” as possible to the users and to the developers. Being “open” enables anyone within the community to actively use the network and participate in the building thereof. Another constraint is that the network should be reliable and low-cost at the same time. These constraints are met in a design using commercial off the shelf (COTS) and home built (low cost) hardware (network boards, antennas and PC hardware) components and open source software. (such as Linux or FreeBSD and other packages well known to the Free software community).

2.2 Technologies

A number of different technologies are available to build wireless computer networks. Most commercial solutions are proprietary to certain vendors or do not use low cost hardware.

The IEEE 802.11 standard (called WiFi in the commercial world) allows users to network their machines using radio technology. Different substandards have formed specifying the bandwidth or radio frequency the networks operate on. The standard defines a number of operation modes which allow for adhoc, point to point and point to multi point networking. Though the standard calls for two transmission technology standards; Direct Spread Spectrum (DSS) and Frequency Hopping Spread Spectrum (FHSS), the market has by and large standardized on DDS for indoor and outdoor point to multipoint use. FHSS, which is more robust against certain types of interference and densely packed endpoints, is currently only seen on long point to point connections; where interference and frequency allocations are at a premium. Such as for example at a aggregation point.

In this project we have chosen the 802.11b as primary standard mostly because of the availability of equipment, open source drivers and the cost of the hardware. IEEE 802.11b is a DSS radio technology supporting link speeds of 1,2,5.5 and 11 Mbit/s. The standard is defined for home and office use, but with special measures (antennas) it is also applicable for crossing longer distances outdoors. (up to a maximum of approximately 15 Km (in a line of sight)) [WirelessNet, WirelessComm]

2.3 Topology

The Network we are building and operating is targeted on a coverage area of 25 square Km, which is the complete city of Leiden, The Netherlands and its surroundings. The total number of people living in this area is approximately 160,000 In this area we want to provide outdoor coverage. For using the network indoors a small antenna connected to the client computer has to be sufficient. The antenna should preferably have a line of sight to the nearest network access point.As the maximum distance between the client and the network access point (a network node) is limited due to the local (FCC-like) national legislation implementing EU/ERC regulation. (restricting maximum radio frequency (RF) output power and restricting antenna gain). Combining this knowledge with the anticipated traffic and bandwidth needs, it shows that we need multiple nodes distributed over the coverage area. The nodes themselves have to be interconnected. A plot of the radio coverage of the current set-up (the historical center of Leiden, (10 square Km)) is shown in figure 1. The interconnection of the nodes is

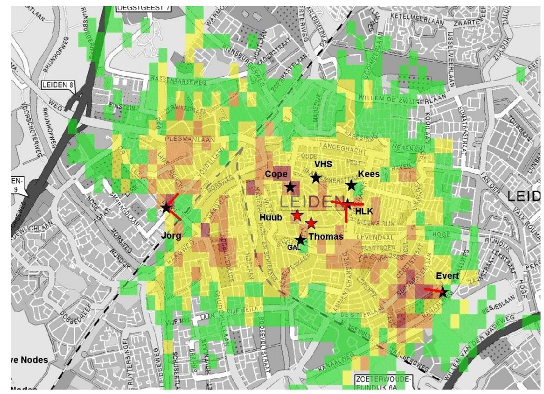

Figure 1: Current radio coverage plot (courtesy of `www.wirelessdesign.nl`)

also using wireless links, making the network completely independent of the local (wired) infrastructure and thus very cost-effective and without significant monthly or other regularly repeating costs.

A mesh between the nodes will be formed, as each node is connected to other nodes by at least 2 different connections. With this approach, adding extra nodes to the network will add redundant paths and therefore will increase the total bandwidth. The topology is comparable to cellular telephony. Cells for users are created. In these cells users share the total available bandwidth. The cells are interconnected by point-to-point wireless connections.

2.4 Radio Planning

In The Netherlands there are 13 channels allowed in the 2.4 GHz frequency band to run radio networks on. In figure 2 it is shown that there are 3 completely separate channels available. Combining this knowledge with the topology and the goal of providing coverage in a fairly big area poses a challenging problem.[Beckmann] The problem is solved by careful selection of the channels, antennas, and the location and polarisation thereof. Also interfer-

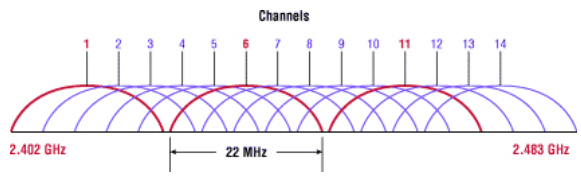

Figure 2: The available channels.

ence on the radio level is a problem. The 2.4 GHz band is in The Netherlands available for a number of licensed and unlicensed applications ranging from microwaves to video-links, vehicle identification systems and radio amateur (ham) use. The use of WiFi in this so-called ISM (Industrial, Scientific, Medical) band is unlicensed, providing the abovementioned channel restrictions are obvserved and the effective output power of the antenna does not exceed 20 dBm (100 mW).

Using radio-planning software we can simulate the propagation of the signal and optimize the location of the different sites. Nevertheless, a site survey is always needed to measure the noise generated by other radio sources and check the signal strength of the already running nodes. Due to the high absorbance of the radio signals by for example trees in the line of sight local measurements are essential in planning a node.

2.5 IP space Planning

The network uses TCP/IP as transport layer, therefore every active element in the network should have an address. Using a private IP version 4 range enough addresses will be available. Using IP version 6 will be a future enhancenment and is not yet implemented. So, as the IP network grows there is a need for not only planning the radio frequency space, but also planning the IP space. The network is using an private IP range, that is assigned on the basis of the different zip code regions in the coverage area combined with the population density and average income per head.

2.6 Site allocation

Once a site is designated by using the planning procedure, it might be a tedious task to get permission of the different building-owners to obtain the permission to have the antennas and equipment installed. Because the not-for-profit ans volunteer-driven nature of this project might be difficult to explain that we are not able to pay the same amount of money as a cellular phone provider, which can be up to Euro 10,000 a month. The volunteers have organized themselves in an official foundation with a statute, and this foundation has managed to generate some positive publicity. Being an official foundation with some media exposure and a good story – a free, fast community network – has been helpful in gaining roof top access free of charge.

Locations that are important to the community, like schools or the town hall are targets to set up nodes. Also cooperating commercial enterprises that want to provide services on the network, or want to make use of the network for private communications (eg. between different branch offices) are quite willing to invest in the equipment and time to set-up and maintain a node.

2.7 Setting up a Node

A typical network node setup consists of a number of antennas and a computer system. We use 2 or more directional antennas to connect to other nodes and one omni-directional antenna for local access of clients. (See figure 3) and a PC or other system to provide the routing and access-point functionality. A typical node setup can be found in figure 4 The partly home-built and partly commercial antennas are connected to a computing platform (right now an Intel based PC with a number of PCI based wireless interfaces is used) This machine runs either Linux or a free BSD flavor and can connect to the local network at the site using wired ethernet. Setting up a network node requires some real hard hardware work to get the antennas lined up and affixed to the building. As we are using directional and polarized antennas to prevent interference the alignment of the antennas is fairly critical. Once the antennas are set up, connection to the node machine is done using low loss coaxial cable. Keeping cable losses to a minimum is important, the length of the cable should be minimized.

Figure 3: Antennas on a building.

Before and after the installation of the hardware a number of throughput, alignment and reliability tests have to be run, to be sure that the set-up will operate as expected. Often, once set up it is quite difficult to physically access the machine and the antennas because mostly they are set up on remote locations in buildings with complex access procedures. A typical test for the reliability is to copy some video data (often comprised of large files) through te node. A test protocol is used to assure the repeatability of the testprocedures. Watchdog devices are used to ensure a clean reboot of the system when some part of the software crashes. The software on the machines is a standard free UNIX distribution stripped down to fit in a minimal hardware configuration. The (kernel) device drivers that are used to control the wireless network cards and some network management utilities are added. For IP routing we use the ZEBRA package which provides OSPF routing through our network.[Zebra, Routing]

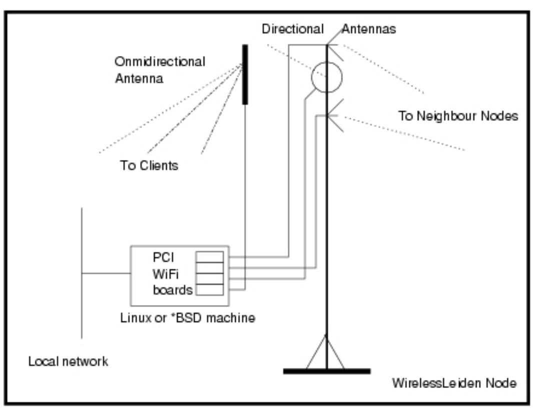

Figure 4: A Node.

A PERL [Perl5] script is used to generate the per-node configuration from our central network repository. Usage of a central configuration database one can manage the integrity and compatibility of the different nodes.

Using a standard off-the-shelf open source operating system enables us to implement a node quite fast while at the same time keeping the flexibility of changing things on all levels when the network grows and the technology changes. Another aspect is the large knowledge-base available within the development and engineering group. Also the open source development model guarantees a fast turn around time in fixing bugs or evaluating features. Last but not least, in a not-for-profit organisation working from donations the initial cost of the software is of major importance.

2.8 Security

Security is currently not applied on the infrastructure level. Of course, all network nodes have appropriate security to secure the boxes itself, but as an infrastructure provider, we have the rule of "security is the responsibility of the user". On the radio level we use a combination of narrow beams to interconnect nodes together with Wired Equivalent Privacy (WEP) or even a WEP infrastructure with dynamic keying. As WEP provides no actual security [Borisov], the user of the infrastructure must be aware of the *in*security of the transported data, and use eg. IPsec.

The nature of the transport layer adds an extra possibility of Denial of Service (DoS) attacks by "jamming" a connection on the radio level. Because we are operating concurrently with other users in the same frequency space this can be a problem. Adding redundant paths together with the appropriate routing protocols is the way to overcome the problem for the user.

2.9 Running a Network Node

The network node is highly self-contained, and does not need on-site maintenance. All software and configuration maintenance, upgrading etc is done from the network using the configurations in the repository. Software level reconfiguring of the node can be done on the fly to cope with the changing architecture.

The Network node can be connected to the users (home) network in order to give the local user wired access to it. Therefore, on the ethernet port DHCP is enabled. Traffic and other operational data on the node is gathered using RRDB and RRDtool [RRDB] and sent to the central repository in regular intervals.

Furthermore maintenance on the antennas is needed. Regular inspections on the state of the antennas and mounting hardware are needed to ensure safe and relable operation.

3 Results

3.1 Applications

During the first year of this project we have succeded in building about 12 network nodes in the Leiden area. These nodes are interlinked with their neighbors by 802.11b links and have access points to accomodate users to connect wirelessly to the network. Applications currently in use are various VPN connections of enterprises giving their employees access to the company network, schools with different locations connected to each other, a video server and some gaming applications. Currently under investigation is the cooperation with a large Internet Service Provider (ISP) to allow them to provide Internet access to the community (ie. the connected users).

Due to the achieved outdoor coverage of the network, applications that require mobile use of the network are possible. These applications are currently being developed by users of the network. We are investigating how these applications will use the network and what features they might need (eg. roaming).

3.2 Problems

Problems that are encountered during the start-up phase of the network can be divided into two groups. There are technical and non-technical problems to be solved.

Technical problems are seen on every level of the network stack. Starting with the physical level, it is difficult to plan the network using the different constraints like noise, limited channels available and natural obstacles. Due to this problem the configuration of the network is constantly evolving. Changing of antenna directions can be difficult once a node is set up.

On the higher levels we have encountered problems with the network drivers for the wireless boards we are using. These problems can seriously affect the throughput and reliability of the network. Here the use of open source software and the open source development model pays off. Problems can be solved within the group, or with help and information gained fron the Internet. Also having a choice between different solutions to the problem helps.

On the IP level having many point-to-point links and a number of applications results in a quite big puzzle to get everything configured correctly. Using a central configuration repository and the use of routing protocols helps, but some problems still remain to be solved. For example when connecting to the Internet (with a number of providers) a routing and numbering issue needs to be solved. Also the latency might pose a problem in some applications.

Furthermore, sometimes the reliability of the hardware can be a problem. Because of cost issues complete (used) PC machines are in use as network nodes. These machines are not as reliable as dedicated routers built as dedicated embedded systems without moving parts (like fans or harddisks). Minimizing the points of failure, testing, validating and proper maintenance helps a lot here. Currently such a small embedded system is in development to assure better reliabilitiy and enhance the mean time between failure of a network node.

Non-technical problems are gaining acceptance within the town and the community. Without a broad acceptance and support of various organisations it is not possible to build this kind of a network in a not-for-profit fashion. Access to rooftops of high buildings etc is essential.However, we do not believe that a for-profit organization has any chance of succeeding at all. The upfront costs of building a network without volunteers are very large. Possible revenue streams will be insuffient to recoup those large costs.

The other difficult task is to manage a large group of volunteers that are actually doing the work. With the growth of the network, also new people are coming in to do the management and the building of the nodes. With every new engineer another degree of freedom is added to the system. managing this task force in an open manner can be difficult.

Also, we see that on the non-technical level the more religious ideas between eg. the different operating systems or engineering solutions on a specific topic is a problem to cope with. (like *BSD vs. Linux) Having a heterogeneous set-up with different operating systems will gain a broarder acceptance within the group and probably builds a more robust network, but will be much more difficult to manage.

3.3 Related work

In different parts of the world wireless communities are developing. In the USA there are a number of leading initiatives [Bawug, Seattlewireless, FreeNetworks], but also in Europe and Australia communities have been formed. The main difference between the Wireless Leiden network and a number of other wireless communities is that Wireless Leiden has definitely not a hobby-network kind of style and set-up. Due to the professionals affiliated with the Wireless Leiden Foundation and the partnerships with major (local) groups of potential users, hardware vendors, the university and content providers it is far beyond the concept of a number of people sharing their DSL connection using wireless technologies. The other main difference is that due to the acceptance by the community and therefore the possibility to set up nodes on a large number of non-individually owned buildings all connections between the network nodes can be wireless. No wired connection is needed. Here the European (or Dutch) mentality of cooperation to achieve the best result may be an advantage.

Another major point is that the infrastructure will be based on open standards and open source software, it is freeing us from vendor lock-ins and is achieving the broadest possible range of applications while providing sustainability of the complete system.

3.4 Outlook

Right now, the network is in full operation, and the first applications are sucessfully being deployed. Due to the rather small group of technically skilled people the main focus of Wireless Leiden has been to set up nodes and provide coverage in the historical center of Leiden. In addition we have concentrated on knowledgeable individuals and professional organizations as first users, because they require less IT-assistance from the volunteers. As this is accomplished the next step is extending the network to the suburbs and connecting the actual private users to the network. For the coming year a target is set to build and install at least one new network node every month to extend the coverage and increase reliability and bandwith. The second target is to set up a structure for effectively help the individual users to connect to the network. A third target is getting more applications running.

New technologies are being tested to cope with the expected growth of the network. Upgrading the links between network nodes to use 802.11a technology (max. 54 Mbit/s) is in test. Also in evaluation is the use of more complex and advanced technologies using mesh or ad-hoc networking. [Hu, Maltz, Royer] and the use of applications that require of Quality Of Service facilities in the network such as IP telephony and wideband video streaming

Doing research in this environment is very attractive: the big advantage is that a testbed (ie. an actual running network) is already deployed, so actual field testing of new technologies is relatively easy.

4 Conclusion

With the use of relatively low cost technologies and open source software it is possible to build a wireless network which is used by the community. Technical problems do exist, but by usage of open source software they can be solved. The process of building a network using a loosely-coupled group of volunteers is not easy but bringing organisation in the group when the network becomes more complex helps a lot. Having the back-up of the community and local enterprises also helps to gain momentum and visibility of the project, which in return speeds up the development and growth of the network.

5 Acknowledgments

The authors wish to thank all people affiliated with the Wireless Leiden foundation, The city of Leiden and the sponsors of the project. Without the dedication and professionalism of these people and organisations this project would not be able to prove its successfulness. Special thanks go to Caroline Beijer and Dirk-Willem van Gulik for their valuable comments.

6 Availability

As the Wireless Leiden Foundation is an open community, all information, software and hardware that is being developed is free to use for everyone under the GPL. A WiKi website is available to share this information. Unfortunately it is in Dutch, but as engineering language is international, with some effort the important technical info can be extracted. The website can be found at:

`http://www.wirelessleiden.nl`

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