Third generation Mobile Networks and Linux Laptops

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Abstract

GSM, GPRS, EDGE, UMTS, HSDPA, HSUPA, 3G, Wifi, WiMax and a shipload of other abbreviations immediately complicate a story. Third Generation wireless networks are hot... For Windows users, that is.
The various Dutch telecom operators try to convince customers with interesting "cheap" rates (only 2 euro per megabyte) and "free" expensive cards for your laptop. But do these cards also work with Linux? And how do these cards and networks operate anyway? What is fastest? What is cheap? Can you do VoIP?
Klaas will answer the above questions in his talk. He will also showcase his own pet project umtsmon - a GUI to control a mobile network connection in a user-friendly fashion.

UMTS in the Netherlands

A few years ago, the auction of the UMTS frequencies in the Netherlands was big news. Seven consortia bid on five licenses for setting up a UMTS network. In the end, all non-mobile operators stepped out and the existing operators bought their licenses for amounts varying from 500 million euro to almost three times that amount. One of the requirements in the auction was that all operators had to ensure that their networks would be in place *by the end of 2006*.
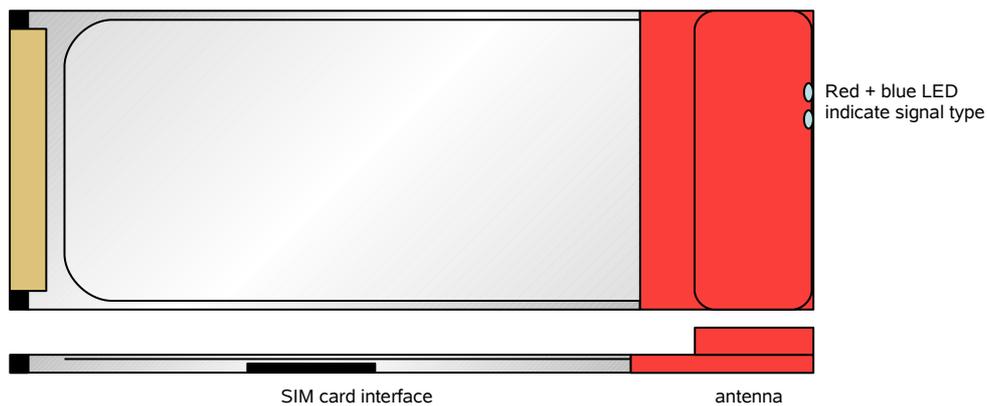
A lot has happened since. The leading Dutch mobile operator KPN nearly went bankrupt because of the purchase of UMTS licenses in several countries and the dotcom crisis reduced the value of their assets. As KPN had liquidity problems, they froze roll-out. The number two, nowadays called Vodafone, was the first to claim to have an UTMS network in the Netherlands. But also Vodafone hasn't seen much return of its invested money… No mobile vendor worldwide (outside Asia) is making money from its UMTS network yet.

UMTS requires a lot of antennas. To get a decent coverage, there are far more antennas required for UMTS than there are for a normal GSM network. The year 2004 through the first half 2006 saw a heated debate on the dangers of radio transmitters in cell phones and antennas to the human health. All kind of research either suggested that one would get sick from living close to an antenna, or would get a heated brain from using a cell phone. Also some people started suggested not to wear a cell in one's trousers as it might reduce virility
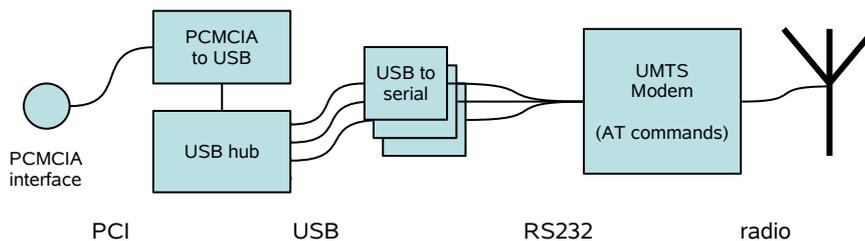
(?!). This made several local municipalities refuse UMTS antennas within their territory. These 'white spots' in UMTS coverage might endanger the timely roll-out of the UMTS networks… It will be interesting to see if the Dutch government is going to overrule the local authorities or whether they are going to loosen their original demands.

At the moment of writing (mid of July 2006), the three largest operators each have coverage for their UMTS networks on the major Dutch cities. Operator number four Orange promises to have a working UMTS network by fall 2006, whereas fifth operator Telfort was bought by KPN and decided not to setup another network. Telfort on the other hand is the only operator to deploy an enhanced version of the GSM network, called EDGE. Apart from a lower throughput, Telfort claims that EDGE will suffice for most uses.

Operator number three T-Mobile actually deployed very little of its UMTS network. They almost immediately switched to an extension of the UMTS protocol called HSDPA (see the Appendix for more info on the differences). This will allow for higher bandwidth and lower latencies. KPN has announced to follow T-Mobile in the last quarter of 2006.

Red + blue LED indicate signal type

SIM card interface   antenna

Top- and side view

PCMCIA to USB

USB to serial

UMTS Modem (AT commands)

PCMCIA interface

USB hub

PCI   USB   RS232   radio

Functional decomposition

Analysis of a PCMCIA UMTS card

KPN, Vodafone and T-Mobile sell PC Cards from Belgian manufacturer "Option" to their customers. In the case of KPN and Vodafone, the author received a "GT 3G Quad" card. The hardware architecture of this card is interesting, and depicted above.[1]

If one inserts the card into a laptop running Linux, Linux will recognize a new USB interface. Three (or four) usbserial devices are connected (via a hub) to that USB interface. Standard Linux kernels do not recognize the VendorID/Product ID for usbserial, but if forced to load by hand, three new serial ports appear on /dev/ttyUSBx.

AT Commands and PPP

Adventurous Penguins immediately type minicom /dev/ttyUSB0 to see what's on the serial devices. Hopefully, they are old enough to remember the good old Hayes-compatible modem era, where one could play with AT Commands and PPP settings for ages before the first connection to the outside world was successful.

Actually, they need to - because that's exactly what you get: all three interfaces are connected to

an UMTS modem with an AT Command set. However, standardization committee 3GPP has standardized the AT commands for 3G network modems, so there are standardized commands to talk to the modem to enter PIN codes, select the network of a mobile operator, send an SMS and such.[2]

There are multiple interfaces to the modem to allow one interface to be used by PPP for the actual network connection, whereas one can use another interface to send AT commands to retrieve the status of modem, network or SIM card.[3]

Connection through mobile phones

The same discovery will be made if you connect a mobile phone through a serial or USB cable to a laptop. At some point, there will be a serial connection – usually at /dev/rfcomm0 – that understands AT commands and can be used to setup a network connection. For mobile phones, the gsmlib[4] project originally was very promising and it also handles phone book extraction and such, but this project appears to be abandoned by now.

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[2] See http://www.3gpp.org/specs/specs.htm

[3] A wealth of information for setting up those Option cards can be found at the PharScape site:
http://www.pharscape.org/

[4] See http://www.pxh.de/fs/gsmlib/index.html

[1] The T-Mobile card has a different layout that does HSDPA. It needs the "nozomi" drivers – see note 3.

Disadvantages of a mobile phone solution when compared to a PC card are that most phones do not allow having a phone conversation and a data transmission at the same time. Such solution also requires carrying an additional cable around. Also keep in mind that most mobile phones are not for use on the UMTS network, and are thus only GPRS capable.

Other laptop cards

Apart from the already mentioned Option cards, operators Orange and Telfort supplied different cards. As Orange doesn't support UMTS yet, they supplied a Sony Ericsson GC79 GPRS + Wifi card. This card is based on the BroadCom 4306 chipset, that fortunately has Linux support for the Wifi part as of Linux kernel 2.6.18. The GPRS part is based on a regular serial port driver.

Telfort supplied a Sierra Wireless Aircard 775. This is a PCMCIA card, but uses the serial_cs driver. Their support site does a good job at explaining how to setup everything.
The serial_cs driver is usually used for modems, so again, a serial port is being made available for communication use.

End of last spring, Laptop manufacturers DELL and IBM announced to start shipping laptops with built-in support for UMTS networks. One should still require to buy a subscription (and a SIM card) from a provider, but no additional PCMCIA card is needed.
As these are amongst the most expensive notebooks money can buy, the author couldn't afford one – so no information on hardware and compatibility is known at this point.

Umtsmon

The only technical thing inhibiting wide usage of UMTS cards on Linux is the above connection setup. By now, this is too complicated for most users. It is possible to integrate this in the regular dialup tools like kinternet. However, these tools cannot handle PIN codes, switching of networks when roaming abroad or limiting the card to a certain network type – see below for its need.
Therefore, the author of this paper started a SourceForge project[5] to create a GUI tool that eases setup and provides specific functionality required for good utilization of UMTS PC cards. At the moment of writing, umtsmon can switch between networks, display signal quality and data traffic, ask for PIN codes and send SMSes.
Probably by autumn 2006, the tool can setup the PPP connection by itself and receive SMSes as well.

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[5] See http://umtsmon.sourceforge.net/
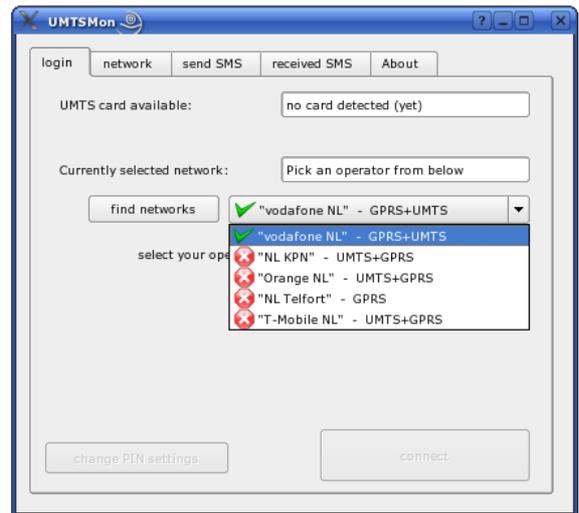
Performance

In theory, UMTS should allow for 384 kbit/s downstream. Any network with HSDPA should be faster. It's time to start measuring. Three different tests were executed:

1. Download all images from the NLUUG website: http://www.nluug.nl/images
2. Download the same set of images from an FTP server
3. Download a single large binary file (vim-5.1.tar.gz, 1445923 bytes) from the NLUUG FTP server

	tech nology	case 1: 88 images over http	case 2: 88 images over ftp	case 3: big file over ftp
fixed line (as reference)	ADSL 2 mbit/s down	5.85 s	13.0 s	7.0 s
KPN	UMTS	48.5 s	106 s	42.1 s
Vodafone business	UMTS	42.9 s	101 s	40.3 s
Vodafone business	GPRS	145 s	347 s	280 s
T-Mobile	UMTS	46.8 s	155 s	42.6 s
T-Mobile	HSDPA	n/a	n/a	n/a
Orange	GPRS	n/a	n/a	n/a
Telfort	EDGE	112 s	237 s	82.5 s

(times to complete, smaller is better, everything downloaded using `wget`)

One thing to note is that several operators try to perform optimizations for web browsing. This is visible in the first test. To compare: KPN downloaded: 517,661 bytes in 89 files; Vodafone downloaded only 234,955 bytes. Only for T-Mobile, this setting is configurable through a web interface.

Keep in mind that `wget` uses an HTTP 1.1 connection, i.e. it downloads all files through the same TCP connection. This is definitely an advantage as setting up a new connection for each file takes considerable more time. Compare with case 2, which are the same 88 images, but now using the FTP protocol.

The UMTS and GPRS networks cause over 2 seconds of latency for each new TCP connection to be made. EDGE and HSDPA should theoretically improve on this, but our measurements don't show that advantage.

In case 2, the UMTS traffic over the T-Mobile network was heavily affected by repeated attempts to switch to HSDPA mode. Usually this connection lasted for a second before the card switched back to UMTS – and usually immediately fell back to GPRS. This explains the odd performance number. At the time of the measurements, the "nozomi" drivers cannot limit the card to a certain (2G, 2.5G, 3G, 3.5G) connection type, yet. Limiting this will improve the numbers, as they varied heavily – T-Mobile actually set the record for UMTS downloading in 99 seconds in one of the test runs, totally ruining the average by consuming 235 seconds in the second…

Download speed in itself is rather good: the third case downloads a single file. All UMTS networks show similar performance of about 33 kilobyte/s, close to the theoretical maximum.

As is to be expected, GPRS was much slower, but EDGE did show off its improved download behaviour: a neat threefold improvement of the download speed.

Applications

The most obvious use of a UMTS card is for e-mail and web browsing. Due to the optimizations that some of the operators perform, web browsing runs at an acceptable speed whereas e-mail downloading does not suffer much when compared to a wired or wifi connection.

Other applications are less of a success. Due to the high roundtrip latencies, running a shell over a SSH connection is really slow: it takes one to two seconds before the characters you type actually appear echoed on the screen.

Also VOIP in itself is hardly possible due to the latencies. The reason that UMTS phones do not have noticeable latencies lies in the fact that they do not use data packets, but setup a CSD channel directly with the antenna. This 64 kbit/s guaranteed bandwidth ensures timely delivery of voice data.

On HSDPA, the latencies are seriously reduced because in this case also a dedicated tunnel is setup for communications. Operator KPN promised that once they deploy HSDPA (somewhere Q3 2006), they will allow customer to run Skype or other SIP communication over their packet switched networks.

What about WiFi ?

Several of the PCMCIA cards also have support for other types of wireless networks. The Web'n'Walk cards as shipped by T-Mobile and the cards shipped by Telfort and Orange also feature WiFi. In case of the Orange card, support is only available through Windows NDIS emulation drivers.

But this brings us to the interesting question: why go for UMTS anyway? Wifi is widely available in hotspots in bars and hotels, airports and in several cases even for free on the streets. Hotspot operators however, usually charge a fee per time unit. In most cases, you have to buy pre-paid cards that allow for a quarter, an hour, three hours or 24 hours of internet access. In most cases, logging out will not prevent the timer from ticking, thus wasting money.

Performance of Wifi is usually only limited by the (ADSL) connection from access point to the internet. This means that in Western Europe, download speeds of a hundred kilobyte per second is usually possible – way better than UMTS.

However, one must remain in the vicinity of the access point whereas UMTS users are free to walk everywhere...

Pricing

Most operators at this moment have two different subscription forms:

- **Pay per MegaByte**
  Depending on the operator and the technology, this can be as low as 50 cents per MB, up to 2 euro per MB.
  In both cases, it usually is cheaper to go for a 5 or 10MB/month bundle or buy a

- **Flatrate**
  In this case, you pay a fixed fee per month. In most cases, there is a fair use policy of 1 GB of traffic per month. Prices vary again per operator and technology. Telfort offers the cheapest (EDGE only) flatrate of 27.50 euro/month. The UMTS and especially

the HSDPA subscriptions of the other operators are twice up to three times more expensive.

If you want to get your UMTS card for free, you have to buy multi-year subscriptions. It's definitely worth shopping around – there are huge price differences and the operators usually have interesting discounts. Keep in mind that some of the vendors will soon upgrade to HSDPA!

Conclusions

UMTS on Linux is feasible. It is suited for regular office use: e-mail, web browsing and instant messaging.

Due to the slow setup of new TCP connections and the large roundtrip latencies, it is not suitable for skype and less suitable for IRC traffic. SSH connections do work, but one sometimes need a little patience.

The main factor inhibiting UMTS and other high-bandwidth mobile technologies is the price.
This is way too much for the average user that sometimes wants to check his e-mail whilst sitting on the edge of the local swimming pool. Most geeks will still have to resort to play Quake to impress members of the other sex…

Appendix: short overview of mobile network technologies

Wireless mobile communication already exists for quite a while. Two famous 'zero' generation devices are the 'Walky Talkies' and the 'Bakkies'. All devices share the same radio frequency. If one wants to talk, he pushes the send button and all others have to listen. It's very easy to eavesdrop – just listen to the right frequency.

During the 80s, national telecom operator PTT installed the first analog cellular networks for mobile communication. Throughout the Netherlands, antennas were erected and "carryable" phones (approx 5 kg!) could call into these networks. The first generation (1G) networks weren't a real success due to very heavy batteries and high costs for the end users.

In 1982, a French organisation called "Groupe Spécial Mobile" had started investigations into a digital wireless communication network. The biggest advantages were the reduction of interference and distortion in the audio and to increase security. At the end of the eighties, the EU agreed to use this new system and standards body ETSI took over maintainer ship. By the end of 1991 the first GSM network was aired in Finland, with the other countries quick to follow. GSM is called a 2G network, and one important aspect is that during a call, the phone has a fixed-bandwidth communication channel to the antenna.

With the rise of mobile computing, this fixed bandwidth imposed a problem for utilising this network for data exchange. There is no need for a full communication channel as users aren't in a constant need for data. A packet switched network like the regular IP protocol would be ideal – where several users together can use the bandwidth. This became the 2.5G network GPRS "General Packet Radio Switch". Due to the packet switching, traffic is no longer taxed per time unit but per megabyte.

Dutch operator Telfort carries another extension to GPRS, called EDGE or "Enhanced Data Rates for GSM Evolution". This 2.75G network changes the way the radio signal is used, thereby tripling the throughput. This impacts both the cell phones and the equipment used by operators. This is why most operators refuse to switch to EDGE and jump to UMTS directly.

A breakthrough in radio technology allowed for a new coding of radio signals. This was called W-CDMA and is essentially different from the TDMA coding of the GSM network. Together with new frequencies that allow higher bandwidths, these 3G networks are called UMTS or "Universal Mobile Telecommunication Systems". As explained in the beginning of this paper, the UMTS network requires all-new equipment.

Another extension to the radio technology of UMTS is called HSDPA or "High Speed Downlink Packet Access". This 3.5G network protocol creates the notion of a dedicated downlink channel. Other improvements are in the area of retransmits and error correction. As well as improved data rates that are associated with HSDPA one of the key benefits that are seen is the reduction on latency, improving the round trip time for applications.

This is not the end of development, the 3.75G technology HSUPA is ready for deployment and 4G networks are being designed right now. And still, the public is afraid of more antennas and the damage of radiation to the human physiology. There is a technology push, but the question remains if the public is interested in those improvements or whether it is "good enough".

network type	generation	upstream	downstream
analog	0G	n/a, push-to-talk voice	n/a, push-to-talk voice
analog	1G	n/a, voice cell phone	n/a, voice cell phone
GSM	2G	4 kbit/s	4 kbit/s
GPRS	2.5G	up to 40 kbit/s	up to 80 kbit/s
EDGE	2.75G	???	up to 238 kbit/s
UMTS	3G	up to 128 kbit/s	up to 384 kbit/s
HSDPA	3.5G	up to 384 kbit/s	up to 10.8 Mbit/s

Appendix: Biography Klaas van Gend

After his first encounter with Silicon Graphics' IRIX during his study at Eindhoven University of Technology in 1993, Klaas has been working with UNIX and Linux ever since.

From 1999 onwards, Klaas has been professionally engaged with embedded Linux software development at various positions with companies like Philips, Océ, Sioux and Siemens.

In his current job as Field Application Engineer Europe at MontaVista Linux Software, he visits a lot of customers across Europe.
Because he didn't want to be dependent on the friendliness of the local systems administrator, he bought a UMTS laptop card.
Meanwhile he tried several cards from different telecom operators.

As of June 2006, Klaas has become a board member of the NLUUG and acts as treasurer to the association.

Klaas also writes as a free-lance author for the Dutch Linux Magazine and several other magazines. He lives with his wife in the Eindhoven area and if he's not busy working or writing, he can be often found in the local cinema.