Tijdschrift van het NERG

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DE VERENIGING NERG

Het NERG is een wetenschappelijke vereniging die zich ten doel stelt de kennis en het wetenschappelijk onderzoek op het gebied van de elektronica, signaalbewerking, communicatie- en informatietechnologie te bevorderen en de verbreiding en toepassing van die kennis te stimuleren.

BESTUUR

LIDMAATSCHAP

Voor het lidmaatschap wende men zich via het correspondentie-adres tot de secretaris of via de NERG website: http://www.nerg.nl. Het lidmaatschap van het NERG staat open voor hen, die aan een universiteit of hogeschool zijn afgestudeerd en die door hun kennis en ervaring bij kunnen dragen aan het NERG. De contributie wordt geheven per kalenderjaar en is inclusief abonnement op het Tijdschrift van het NERG en deelname aan vergaderingen, lezingen en excursies.
De jaarlijkse contributie bedraagt voor gewone leden € 43,- en voor studentleden € 21,50. Bij automatische incasso wordt € 2,- korting verleend. Gevorderde studenten aan een universiteit of hogeschool komen in aanmerking voor het studentlidmaatschap. In bepaalde gevallen kunnen ook andere leden, na overleg met de penningmeester voor een gereduceerde contributie in aanmerking komen.

HET TIJDSCHRIFT

Het tijdschrift verschijnt vijf maal per jaar. Opgenomen worden artikelen op het gebied van de elektronica, signaalbewerking, communicatie- en informatietechnologie. Auteurs, die publicatie van hun onderzoek in het tijdschrift overwegen, wordt verzocht vroegtijdig contact op te nemen met de hoofdredacteur of een lid van de Tijdschriftcommissie.

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Van de redactie

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Voor u ligt het eerste nummer van het Tijdschrift van 2007. Dit jaar zal een overgangsjaar zijn naar een digitale versie van het Tijdschrift. Naast de papieren uitgave zal het Tijdschrift voor leden ook elektronisch te raadplegen zijn via de website. Voorlopig zal echter de papieren uitgave van het Tijdschrift in de huidige vorm blijven voortbestaan. In de toekomst zal het aantal uitgaven van de papieren versie per jaar wellicht gaan afnemen tot een aantal van circa twee.

Verder kan ik melden dat we een nieuw redactielid hebben gevonden. Het is Paul van Wijk. Paul werkt bij TNO ICT (het voormalige KPN Research) als senior scientist. William de Waard en Dion Kant hebben de redactie verlaten omdat zij hiervoor geen tijd meer konden vrijmaken. De redactie bedankt William en Dion voor hun inzet de afgelopen jaren.

Dit nummer staat voor het grootste deel in het teken van de nederlandse bijdragen aan de FITCE (Federation of Telecommunications Engineers of the European Community) conferentie van 2006. Tijdens de gezamenlijke themabijeenkomst met KIVI-NIRIA zijn de bijhorende presentaties nog een keer gegeven.

Verder in dit nummer een artikel uit de reeks "Scanning our Past from the Netherlands" die eerder verscheen in de Proceedings van de IEEE. Het artikel gaat over het begin van radio-astronomie in Nederland.

Multiple Wireless Protocol Advertising System, Enabling Automatic Access Selection and Local Services

S.A. Houben, N.H.G. Baken,
P. Hervé, R. Smets

Abstract

We have examined the efficiency within wireless access options for mobile devices and discovered that a classical pitfall is revisited. As with the proliferation of services in the portfolio of incumbents, leading to a number of coexisting so called stovepipes, we see an isomorphic phenomenon evolve in multi-modal mobile devices, leading to an inefficient development of vertical stack technical solutions for each different mode. It is the first time we found the optimal technical and commercial fit, i.e. the internal device solution and external service provider solution respectively, with tremendous benefits for the end user. Migration from vertical towards horizontal solutions, the tilting on device level, not only decreases costs but also hugely increases the flexibility for the introduction of new customized solutions.

This paper outlines a unique technology called XAS that enables automatic access selection for a requested service, based on qualifiers such as available bandwidth, provided QoS and connection costs. Clever implementation of this system will extend commercial utilization further than access selection only. This system will also enhance the performance of existing devices in terms of standby time and security. In addition, it will open vast opportunities to introduce new and exciting services based on the location of the user. The outlined solution is not merely a theoretical exercise, but already has been built in a realistic pre-commercial demonstrator with which promising results have been obtained. Lucent Technologies has filed a patent for the concept of this system.

I. Introduction

During the last decade the GSM technology (and more recently GPRS and UMTS) have made an impressive entry into a world where fixed telephony dominated the telecommunication sector. Established and new providers of these technologies used the same economic model as the fixed-line providers. An end-user was obliged to obtain a subscription from a particular provider who also owned the network. Roaming between wireless networks was not possible.

Other networks, based on different wireless technologies such as WiFi, Bluetooth, and in the near future WiMaX, UWB and ZigBee are not necessarily bound to one provider (although the continuously growing number of hotspots operated by a single provider might suggest otherwise). However, interchanging between these technologies to optimize connection characteristics such as available bandwidth, service, QoS and cost is in the current situation not possible. This inability to interchange between providers and technologies is depicted by the stovepipes in Figure 1C and 1G.

The foundations of these stovepipes were built a few decades ago. At that time the selection of a network for a communication service such as telephony or cable television was very simple; there was only one network that offered the service, and there was only one company that could provide the requested service over that network. Monopolies existed that were confined to the one service they offered, because all companies that were active in this sector were strictly regulated. This relation is shown in Figure 1A. After deregulation of the sector new competitors came to the market (multiple bars), which is depicted in Figure 1B. Being active in the telecommunication sector and looking for more revenues, these providers expanded their businesses to other service areas, as can be seen in Figure 1C. The introduction of triple play (telep-

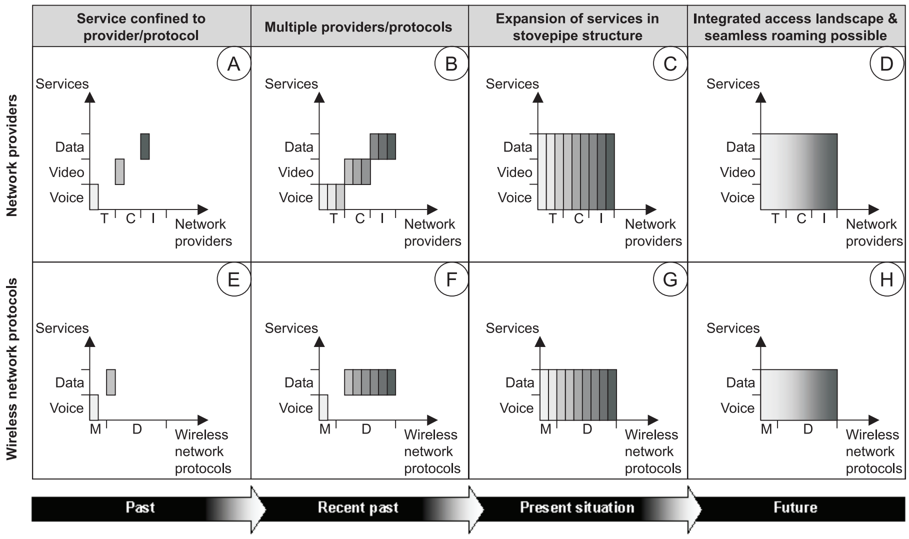


Figure 1: Stovepipe formation prevents dynamic switching between network providers and wireless network protocols. T = Telecom provider, C = Cable provider, I = Internet service provider, M = Mobile telephony protocols, D = Data protocols.

hony, television and internet by a single provider) is an example of this. In this scenario, which presents the current situation in the telecommunication sector, different providers can be selected that provide all kinds of services. However, dynamic switching between these providers is not possible, leading to the stovepipe structure depicted by the multiple bars. In conclusion, users are statically bound to individual providers and their networks.

Similar stovepipe formation can be observed on a different level. Technical solutions in mobile devices have also resulted in the formation of stovepipes (Figure 1G). The current commercial solutions do not provide the possibility to switch dynamically between different access technologies. Wireless voice services used to be offered exclusively over the GSM-network and wireless data services needed specialized protocols such as WiFi and Bluetooth (Figure 1E). The number of wireless technologies and their associated protocols increased at a rapid pace (multiple bars) resulting in the representation of Figure 1F. With the introduction of VoIP (Voice over Internet Protocol) it became possible to employ voice services over data networks, and the appearance of GPRS and UMTS enabled data services over the mobile networks. This led to the present situation of Figure 1G. In this situation many different wireless technologies coexist that provide both data services and voice services. Dynamic switching between the different technologies is very difficult, because of the different protocols belonging to these technologies. This has resulted in a stovepipe structure where users are statically bound to a protocol and roaming between different protocols is not possible.

It is expected that in the future the multiplicity of providers and network protocols will remain [1]. However, a logical next step is that this stovepipe structure in the cases of both the network provider and the network protocols will disappear, because there is a demand from end users to establish connections to the best available protocol at the lowest cost for any service. Such a situation is depicted in Figure 1D and 1H. In this future scenario, the stovepipe structure that separates individual providers and protocols has disappeared and has been replaced by an integrated access landscape in which roaming between different providers and protocols is possible.

When dynamic switching becomes possible, the selection process should not be left to the end user. Users should not be troubled with constantly having to determine what the best available access connection is. To that end a system is required that performs this access selection for them.

In summary, the current jungle of wireless technologies does not allow interchanging between providers and technologies. Automatic selection of the best available technology and provider to establish a data connection would therefore very much benefit the end-user. For this purpose a system is required that efficiently compares all available access options in the area in terms of available connection resources and conditions when the user requests data access.

This can be achieved with an advertisement system that is implemented in both base stations and mobile devices. This system is elaborated on in the remainder of this paper.

II. Multiple wireless protocol advertising system

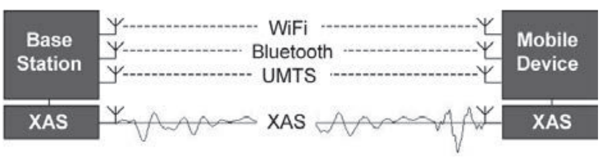
We propose an advertisement system called XAS. This stands for "X Advertising System" pronounce "Access". This system broadcasts messages unidirectionally to all nodes in its direct environment. These messages have to contain the required data on the available protocols of the mobile device or base station. The setup of XAS is schematically depicted in Figure 2.

This figure shows three protocols that the mobile device and the base station have in common and could be used by the mobile device to obtain network connectivity. The base station broadcasts XAS messages containing information on these protocols, including the available resources (bandwidth, QoS) and conditions (costs). Because the mobile device will receive this information from all nearby base stations, it becomes possible to compare the connection resources and conditions and choose the best available option. If certain selection rules are implemented as policies that resemble the preferences of the user, automatic access selection can be employed.

Besides cost advantages for the user, an advertisement system will benefit the user in another way. It can reduce the negative impact of idle adapters on the standby time of mobile devices.

The direct implication of the increasing number of access protocols is that in order to detect the availability of these various protocols, the corresponding network interface on a user mobile station needs to be active. Wireless access interfaces in handhelds can consume a considerable part of the total power consumption as is shown in Figure 3. It can be observed from this figure that the power consumption of a WiFi-card in a typical handheld device can amount to almost 50% of the total power consumption of the device. This results in a substantial reduction of battery lifetime.

Figure 2: Setup of the advertisement system XAS.



When using XAS, all wireless interface adapters will be switched off by default, but when a service started by the user requests a network connection, only the automatically selected network interface adapter will be switched on. XAS requires an additional wireless adapter that will consume power. However, instead of power being consumed by multiple interfaces, only one low-power interface will deplete the battery in a very modest way. The power consumed by the low-power XAS protocol is substantially lower than any single existing protocol adapter would consume, because only the low power receiver remains active. This way a reduction in power consumption is achieved.

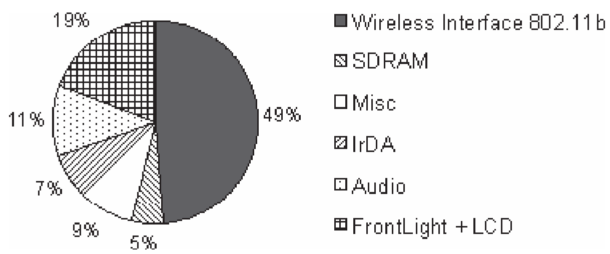
In addition, the ability to advertise messages opens up opportunities for value added services. These value added services are not the major reason a system such as XAS should be developed, but it could provide commercial opportunities that would increase the commercial feasibility of the system.

The value added services that are created by the XAS system are based on the fact that it is very easy to include customized information in the messages broadcast. This extra information can be of any kind and has few restrictions.

There are several reasons one can think of why it would be useful for both users and commercial parties to detect each other's presence. Users are interested in detecting services that base stations can provide, and in detecting the presence of other users that they can share a service with. Service providers are interested in information on nearby users for all sorts of commercial purposes, and interested in information on other nearby base stations for network configuration services.

There are two types of terminals, base stations and mobile devices, and therefore four types of interactions. These four types of interactions are shown in the four quadrants of Figure 4. Every quadrant

Figure 3: Power consumption of a WiFi-interface in a PDA (source: [2])



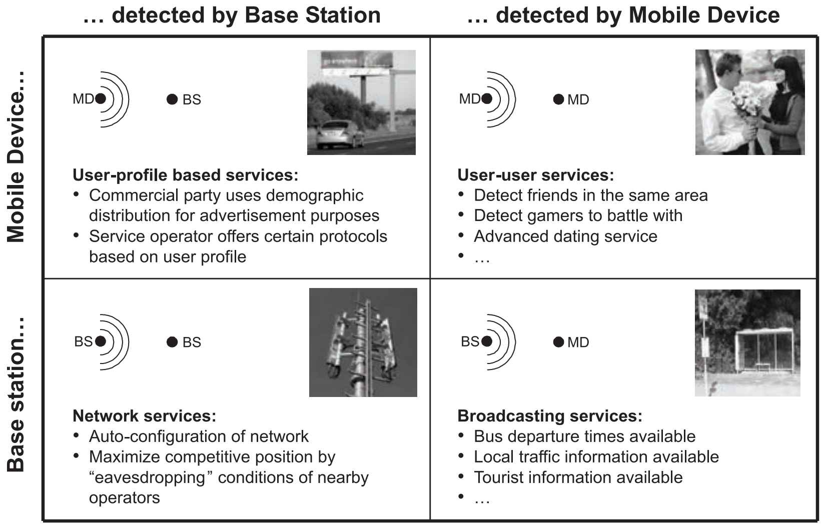


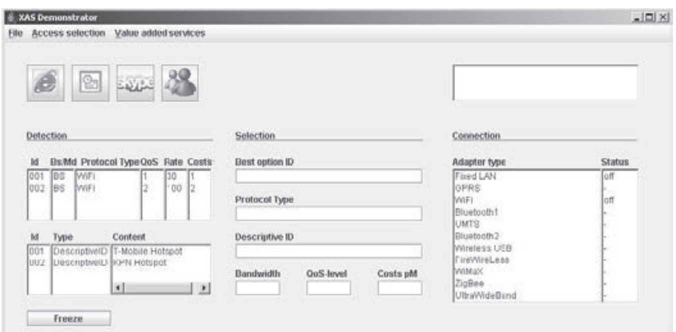
Figure 4: XAS enables four types of detection services.

shows examples services that can be enabled. It is important to observe that these services do not necessarily have to be relevant to the telecommunication sector. They are of potential value in other sectors as well.

User-profile based services enable the futuristic scenario from the movie "Minority report". In this movie a person walks through a shopping mall and is being addressed by billboards by his name. Apparently, these billboards are able to recognize instantaneously the profile of the people in their direct neighbourhood. This value added service can be enabled with XAS. Mobile devices can include a simple profile (gender, age) of their owner in their broadcasted messages. Billboards can receive these messages and customize the displayed content to the dynamic demographic distribution of people in their direct surroundings.

Examples of interesting user-user services: Mobile devices would be able to detect other devices in the area, e.g., friends in the area to chat with or exchange personal files, gamers to battle with via a WiFi connection in a train or airplane.
And example of network services: Multiple WiFi access points within each others' range could advertise their channel utilization and automatically configure their wireless channels to ensure the least interference.
And fourthly, an example of a possible broadcasting service: A base station near a bus station could broadcast that it can provide the bus departure times. If the user of the mobile device is interested, he or she can simply open an accompanying link to establish the WiFi-connection that presents this data.

Figure 5: Screenshot of the XAS demonstrator application.



III. Implementation of the XAS-demonstrator

It was mentioned earlier that the XAS concept has been build in a pre-commercial demonstrator. The demonstrator setup consists of three nodes, two laptops (mobile devices) and a PC (base station). The XAS messages were broadcasted by a radio unit implemented in hardware.

The radio unit of the nodes in the demonstrator setup was realized with a transceiver-module mounted on a FPGA (Field Programmable Gate Array) development board. The transceiver operated in an unlicensed frequency band at 434 MHz. The datarate was set at 19.2 kbps using FSK (Frequency Shift Keying). The employed Medium Access Control algorithm was a form of Carrier Sense Multiple Access based on the 802.11 standard.

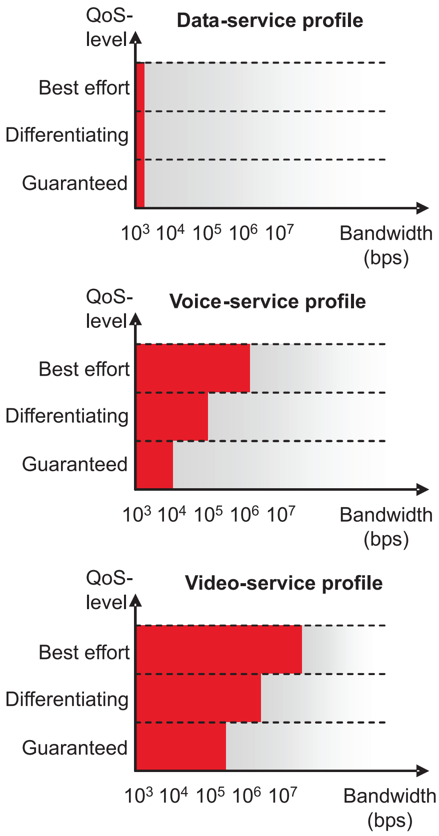
Software installed on the devices controlled the radio unit. This software application composed the content for the outgoing message and processed the content of the incoming messages. A screenshot of the demonstrator is depicted in Figure 5.

IV. The XAS demonstrator shows the capabilities and opportunities of XAS in four scenarios

The demonstrator has been build to display the capabilities and opportunities of XAS in four scenarios. Firstly, it demonstrates the capability of automatic access selection. Secondly, it shows the opportunities of broadcasting services. Thirdly, it shows the possibility of user-user services. And finally, it displays the benefits of user profile based services.

The first scenario shows the capability of automatic access selection. Available access options and corresponding available resources and conditions are detected. These access resources in terms of available bandwidth and QoS were matched to the requirements of a started service. These requirements were based on the profile of the service. Three profiles were defined for the demonstrator. The first profile was meant for data services that would require limited available bandwidth and QoS. An example that fits this profile is an email application. The second profile was intended for voice services that require limited available bandwidth but a high QoS-level. The third profile was customized to video services and required the availability of considerable connection resources. These profiles can be observed in Figure 6. When a service was started, the demonstrator showed the selection of the access option with the lowest cost that satisfied the requirements of the requested service.

Figure 6: Example of service requirement profiles. This example differentiates three types of services.



The second scenario shows the ability to provide broadcasting services. A base station can advertise the availability of certain local information in its broadcasted XAS messages. If the user is interested, he or she can check what local information is available and view the actual content by opening a link.

The third scenario shows an example of user-user services. A mobile device has the possibility to designate other devices as "friends". When two friendly mobile devices move within each others' reach, both nodes can (if desired) receive an alert indicating the presence of the other node.

The fourth scenario presents the ability to provide user profile based services. Knowledge on the demographic distribution of people can be obtained by collecting the broadcasted profiles of the owners of mobile devices in the direct surrounding of the base station. Random variations in this distribution can be used to customize commercial advertisements and billboards, so that the displayed ads fit the profile of the majority of people passing by.

Many variations on these services can be developed that use the ability to advertise limited information to surrounding nodes. The examples merely show a few possibilities of interesting services that are based on the location of the user.

V. XAS Reduces the negative effect of idle adapters on the standby time of mobile devices

Besides enabling access selection and making value adding detection services possible, another reason to implement an advertisement system such as XAS was to reduce the power consumed by idle interfaces.

Device/component	Type	Active current[1]	Idle current[1]
Compaq I-paq H3800 w-pack	PDA	250 mA	5.6 mA
Palm Lifedrive	PDA	277 mA	4.2 mA
Qtek s100 (or MDA compact)	PDA	400 mA	6.7 mA
ORiNOCO PC Gold	WiFi-card	161 mA	12 mA
Cisco AIR-PCM350	WiFi-card	216 mA	9 mA
RX5000	Receiver	3.8 mA	-
TX5000	Transmitter	7.5 mA	-

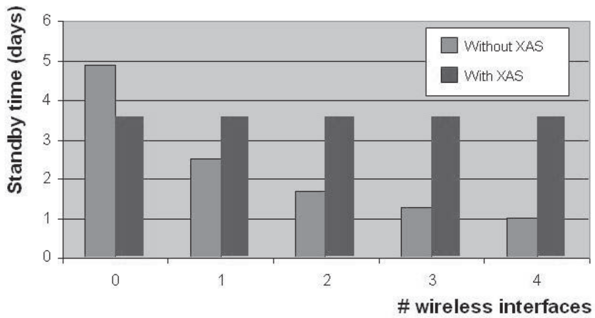
Table I: Power consumption characteristics

The achievable gain in standby time using XAS was estimated. To calculate this theoretical gain in power consumption, three properties need to be known: The power consumption of the mobile device, the power consumption of a wireless network interface and the power consumption of XAS.

This exercise has considered a scenario with a PDA with one network interface (WiFi). For the power consumption of the PDA an average standby power consumption was based on the power characteristics of three popular PDAs (Compaq I-paq H3800, Palm Lifedrive, Qtek s100). For the power consumption of a network adapter the average power usage of two WiFi cards (ORiNOCO PC Gold, Cisco AIR-PCM350) was taken [3]. The power consumed by XAS was based on the characteristics of the power efficient RX5000 and TX5000 chips (RF Monolithics, Inc [4]). The used figures to calculate the achievable power gain can be observed in Table 1.

This exercise assumes active PDA usage of 15 minutes per day and active usage of wireless adapters of 15 minutes per day. Figure 7 shows the calculated standby times of the PDA with and without use of XAS. It can be observed from this chart that configurations with one or more WiFi-cards diminish the standby time of the device. The configuration with XAS, however, reduces this negative influence of idle adapters on the standby time of the mobile device.

Figure 7: Standby time of an average PDA without and with XAS, assuming 15 minutes of voice services per day, 15 minutes of wireless data services per day.



VI. Conclusions

In the present situation, the variety in protocols and corresponding connectivity options has given rise to three challenges. The first is to enable automatic access selection. The second challenge is to reduce the negative influences of idle adapters on the standby time of mobile devices. The third challenge is to make detection services possible.

The common denominator of these challenges is the absence of a way to retrieve immediate information on available connection resources, relevant price conditions and other node characteristics of both base stations and mobile devices. This paper outlines a unique system called XAS that provides a solution to these three challenges. The concept of XAS is that base stations and mobile devices broadcast unidirectional messages to all nodes in their direct environment. These low power messages contain the desired data on access resources and conditions, disclose the availability of protocols and provide basic information about the node.

With this information available real-time, access selection becomes possible and node characteristic information enables all sorts of value added services. Moreover, idle protocols can be switched off as interfaces no longer need to be switched on permanently to detect the availability of connectivity options. The latter results in reduced power consumption and diminished security threats.

A demonstrator has been successfully built and displayed the technical feasibility and functionality of XAS. The concept of automatic access selection can now be shown and proved that XAS indeed results in the selection of the best available option, yielding major benefits for the user. Theoretical exercises show that power consumption savings of more than 40% are realistic for a single adapter configuration, and the performance is even better in multiple adapter configurations. The demonstrator also shows the possibility for various value added services, which increase the commercial value of XAS.

1 Active/idle power consumption of PDAs determined by dividing battery capacity by active/standby times as indicated by vendor. Power consumption characteristics of WiFi-cards obtained from [2]. Power consumption of transmitter/receiver obtained from [3].

References

[1] Baken, N.H.G.; Boven, E. van; Hartog, F. den; Hekmat, R. *A Four-Tiered Hierarchy in a Converged Fixed-Mobile Architecture, Enabling Personal Networks*. Delft University of Technology, KPN, TNO Telecom. 2004

[2] Agarwal, Y.; Rajesh, G.K.; *On demand paging using Bluetooth radios on 802.11 based networks.* School of Information and Computer Science, University of California at Irvine; Dept. of Computer Science and Engineering, University of California at San Diego. 2003.

[3] Shih, E.; Bahl, P.; Sinclair, M.J.; *Wake on wireless: an event driven energy saving strategy for battery operated devices*. Massachusetts Institute of Technology, Microsoft Research. 2002.

[4] RF Monolithics, Inc.; *TX5000/RX5000 Datasheet*

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Broadband Services on Rail Tracks; The business case for fast roaming WLAN

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Movares / TU Delft

Abstract
Wireless broadband in trains is a today's topic of interest for many technology vendors and entrepreneurs. Railway travelers are very enthusiastic about these services. However, it is not so obvious to make the business case go and fly. There are several reasons for this, the first one is obvious: where do the revenues come from? Do railway travelers want to pay for these services and how many users are expected on a daily basis? The second reason concerns technology. Broadband technology such as WiMAX is not yet mature. In this paper, a strategy is proposed for introducing wireless broadband, i.e. internet broadband access in trains, taking into account both the Commercial Portfolio (CPF) and the Technical Portfolio (TPF). Considering the CPF, there exist several opportunities to create value-added services to end-users and business support processes. Broadband applications in trains can be seen as an extra services making public transport more attractive. In this paper we will demonstrate an independent test and its performance from which new results are presented. The test set-up deals with both layer-2 and -3 handover from different vendors, in which the focus is specifically on the performance of centralized versus decentralized intelligence in combination with 802.11i security mechanisms. Furthermore, a business case scenario is presented, based on a net-present value calculation. We conclude that there are definitely business opportunities for broadband applications in trains!

I. Introduction
Mobility in the Netherlands is an ever-growing problem. Politicians and researchers are continuously looking for measures that will ease the pressure on traffic congestion and its inevitable economic and environmental consequences [1]. The more time people spend in traffic jams, the more unproductive they are. Furthermore, the increasing amount of CO_2 and fine dust emission is causing health problems and adds-up to the Greenhouse effect. In order to maintain mobility tremendous amounts of investments are done in increasing traffic capacity and probably in road-pricing in the near future.

At the same time, there is little attention for making public transport attractive as possible means to contribute to a solution. In this light, our study focuses on the opportunities of on-train broadband ICT services to improve travelers' comfort. We claim that with little investments in broadband ICT, services for public transport can be made far more appealing, attracting travelers currently using other modalities.

Starting from an analysis of the status quo on information and communication services for railway passengers, the study continues with a vision on a future scenario. In further chapters the roadmap is explored in terms of commercial, technical and financial portfolios.

A. Status quo
The reason why public transport is not really popular in the Netherlands nowadays is to a large extent due to the level of comfort that traveler's experience. Broadly speaking three main issues exist in this context.
Firstly, traveling by public transport in general takes more time than by car. It is not really flexible; you have to be exactly in time, because else it will cost you probably a half hour delay.

However in rush hours, which are starting still earlier and ending later, difference is already starting to vanish

Secondly, the lack of sufficient information provisioning to travelers is a main issue, especially when unprecedented situations occur. Exactly in these situations people need dynamic, up-to-date information to keep their delay or waiting time as small as possible.

The third issue is the deficiency of service provisioning to travelers. Main advantage of public transport is the ability to use traveling time efficiently. To be able to spend time more effective, business travelers and commuters need communication services to connect to all kind of information resources. Other travelers may wish to relax. However, the services are just not there.

What if we improved the level of convenience that railway travelers experience? And what if railway passengers experienced the same feeling as if they were at home, sitting on the couch? Would that attract people out of their cars into public transport?

Our statement claims that with relatively small investments in broadband ICT services (compared to the euros spent on car-related infrastructure), public transport can be made far more appealing, attracting travelers using currently using other modalities.

B. Future Commercial Portfolio

Based on the analysis of the current situation of comfort experience by railway travelers, a long list of innovative, value-added services can be mentioned. In this section we will discuss the most attractive ones that will likely to be offered in the near future to commuters.

Business travelers like to spend their time efficiently and have a 'mobile office' with a full range communications suite, enabling voice and high speed data communications. Combined with leisure services like infotainment, video on demand and gaming, commuters will forget about the extra time it takes to travel by public transport.

Traffic updates can be communicated more frequent to travelers, as relevant and dynamic traffic information may be pushed according to the user's profile. Besides, broadband services in trains may also be used for compensating the inconvenience suffered by travelers in unprecedented delays. For example, in such situations wireless services are costless, so that travelers may spend their waiting time more efficient.

In addition, a combination can be made with the railway operator's business processes for example remote surveillance (vandalism, terrorist threats) and the online engineer. Finally, motorways and railway sections are often co-located. It is possible to strategically place base stations that services can be provided to other modalities and market segments. In this scope, Streetlight [2] may very well be used as access technology to the last mile (Pico cell).

II. Technical portfolio

In every communications system there is a trade-off between distance, bandwidth, speed (of either/both sender & receiver) and quality of service. Marketing managers are frequently claiming vast ranges combined with maximum theoretical throughputs, but Maxwell's Equations cannot be ignored. When the range from sender to receiver is extended, it has to have impact on either mobility, quality of service or throughput. Jeffrey Belk from Qualcomm wrote a clear paper on the implications of throughput and distance on system performance [3]. As a matter of fact, you can't have megabits of throughput over very large ranges with fast moving vehicles.

Recognizing this subtle interdependency the conclusion is made that obviously the radio cells need to become smaller with the increasing demands for personal networks and their growing needs for broadband applications [4]. Another reason why radio cells need to be small has everything to do with the number of served users. The capacity at one access point or base station is limited. To be able to serve many users with high throughput, the cells obviously have to be smaller. This has also impact to the fixed network architecture: wireless networks are an extension to a vast underlying fixed network. The smaller the radio cells, the more fixed access network capacity will be required.

The wide-area concept of UMTS and mobile WiMAX (IEEE 802.16e) for broadband to concentrated fast-moving users in trains is contradictory to this vision.

C. Network Architectures

Two interesting practical network architecture scenarios appear seam to be suitable for providing communications to the train:

- **An end-to-end network architecture**: handheld wireless devices or laptop interface cards connect directly to a base station.
- **A two-tiered network architecture**: network access in the last-mile is divided into two layers; one layer providing the backhaul, the other one a small radio cell (Pico cell) around a receiving station.

D. Boundary Conditions

Railroad environments are not the simplest environments for deploying communications infrastructures. Beside possible problems with electromagnetic interference, other characteristics make it extra complex. A couple of things need to be kept in mind:

- Trains are steel cages; the radio signal attenuates significantly when entering the train. This may be in order of 15 to 20 dB.
- The length of trains may be up to 400 meters for international trains (norm for the length of trains is the size of the platform). For example the signal is well received at the front, but badly at the back.
- Trains do not continuously drive the same track. More complex, carriages are frequently exchanged to adapt to traffic needs.

Scenario 1: end-to-end service architecture

Two state-of-the-art technologies are considered in this type of architecture design.

UMTS: for fast moving users UMTS is currently the fastest mobile access technology available. With upcoming developments HSDPA (release 5) / HSUPA (release 6) for mobile devices (Cell phones and PDA's) it is the best suitable solution for the near future.

Mobile WiMAX: small scale deployment of this promising technology along major roads and railways is not to be expected before 2007 / 2008. This is because the standard has not yet been approved. And if it is ready, there are quite some steps in the design phase before customers can enjoy mobile WiMAX. When compared to UMTS, the 3G standard was finished in 1998 and it has only been since 2004/2005 that the network is up and running in large parts of the Netherlands (Vodafone, KPN and T-Mobile)

The major distinction between UMTS and mobile WiMAX is that the design approach of UMTS was to support for a large part voice traffic and a smaller part data traffic. WiMAX is solely dedicated to data traffic.

This architecture scenario has a number of shortcomings:

- As well UMTS as WiMAX-16e is not appropriate for use in high traffic concentrated areas, like trains and other public 'hotspots'.
- Services which require large amount of data in either up- or downlink cannot be handled, like uploading camera images or video on demand.
- For both technologies attenuation of radio signals to users on the train is significant. Reception might not be sufficient for reliable data transmission.

For illustration, an end-to-end solution based on WiFi is not suited. Research done with WLAN signal propagation in a railway environment shows that maximal range is about 200 meters. The loss of the radio signal within the train compared to outside the train is approximately 15 dB. The loss caused by the train window is found to be 25 dB on average in the same study.

E. Scenario 2: two-tiered architecture

This scenario does solve the shortcomings mentioned above in the end-to-end scenario. Meanwhile, it introduces some other complexities and requires more network functionalities built-in to trains. Figure 1 represents the two-layered architecture. As can be seen, street furniture (Streetlight) is very suitable to function as base station and serve both railway tracks as motorways.

Instead of an end-to-end network architecture, the wireless last mile is split up into two separate access networks, consisting of a wireless backhaul and a wireless LAN on board.

Tier 1: the backhaul

Different technologies can be used in the backhaul (tier-1); for example UMTS, WiMAX (IEEE 802.16) and WLAN (IEEE 802.11).

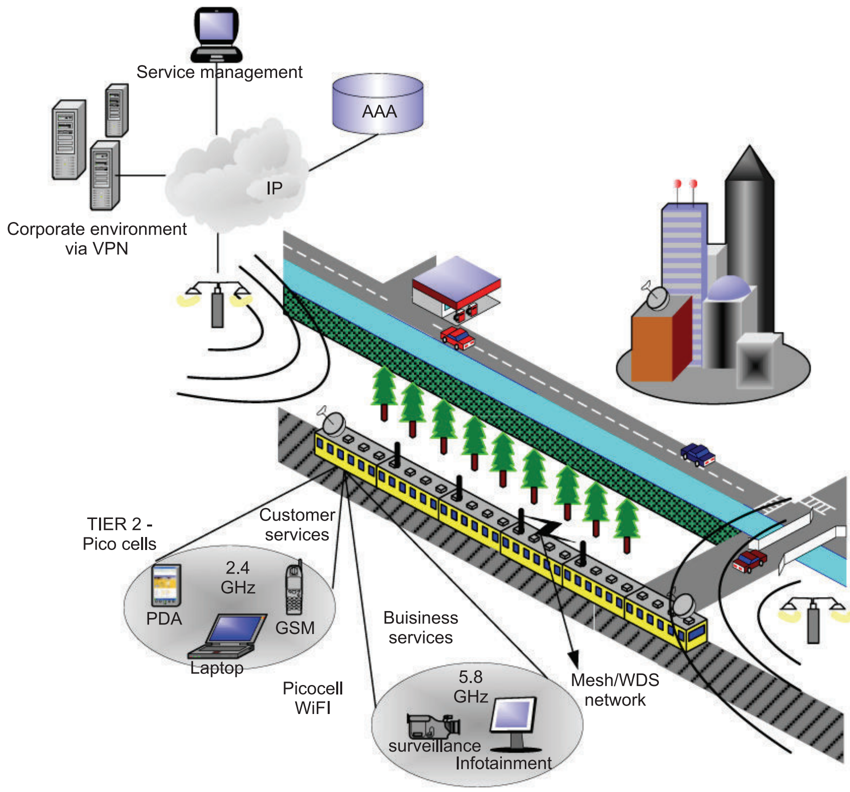

Figure 1: two-tiered network architecture for wireless broadband to fast moving trains

UMTS seems on forehand most feasible for providing the backhaul, because it is already available in large parts of the Netherlands. Especially in urban areas of the Netherlands (Randstad) radio coverage is good. UMTS is currently used as wireless backhaul to trains in a trial project between Amsterdam and Utrecht.
However, UMTS is a short term solution and will not have the right properties for providing the broadband value-added services to both business processes and railway passengers in the near future. This is due to the following arguments.
The main drawbacks of using UMTS in the backhaul are its average throughput, latency and cost. When 20 people in a compartment use broadband services, the backhaul is the bottleneck. Besides, the latency of 200-300ms is too high to serve delay sensitive applications.

For the backhaul two other promising alternatives exist: fixed wireless WiMAX (IEEE 802.16-2004) and WLAN (IEEE 802.11). Analysis of the standard shows that WiMAX has in theory the best properties for providing the wireless backhaul to the train, in terms of channel capacity and end-to-end network latency.

However, in this scenario WLAN (IEEE 802.11) must not be forgotten. The WiMAX physical and MAC-layer of IEEE 802.16-2004 are very similar to the IEEE 802.11 (WLAN) standard. Both use OFDM as technology in the physical layer, and the way security in WiMAX is designed is to a large extent the same as 802.11i, which means that it is secure. Of course, there are differences in the way the protocol is designed, merely due to the different frequencies the WiMAX product has to support. But the key point is that the performance of WiMAX to fast-moving users is not superior to 802.11.

WiMAX products have just been certified; hence new products are not yet over teething troubles. Moreover, new technical products are far more expensive than those in a later stage in the product life cycle. The only major difference in favor of WiMAX is its broader available spectrum and larger transmit power (through which a larger area can be covered).
On the other hand, the 802.11 protocol is well developed, products are mass-produced and cheap. Wireless LAN does approach the performance of WiMAX, and more important: it is widely available and thoroughly tested. Furthermore, in terms of cost WLAN is also favorable.

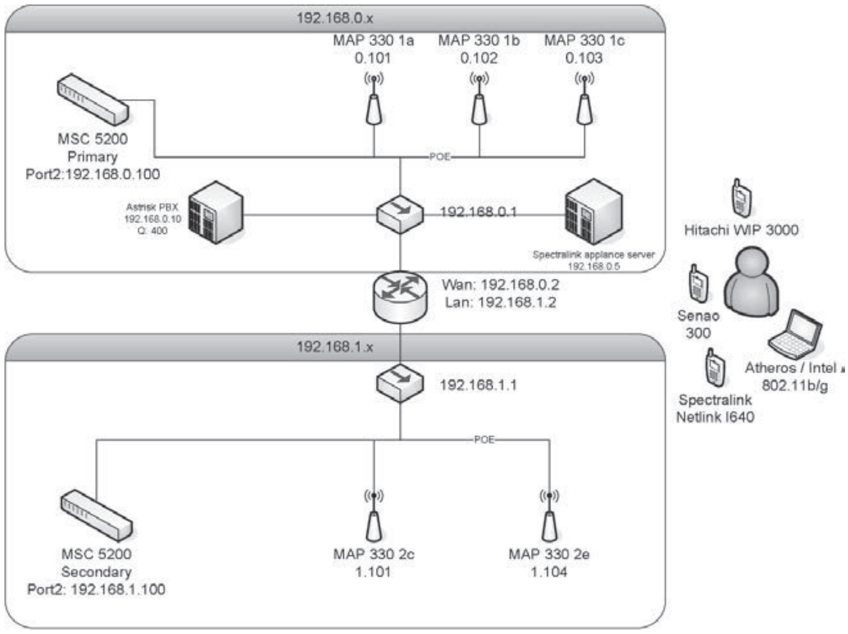

Figure 2: Set-up from Colubris, one of the tested vendors

Tier 2: the Pico cell

For the Pico Cell, the second tier, the only feasible choice is WiFi. Almost all notebooks that are sold today have got a WiFi network adapter incorporated. Furthermore, more and more PDA's and also mobile phones are WiFi enabled. Access to WiFi networks is easy and understandable for many users, for two reasons. Firstly, they use it at the office and at home, thus are familiar with it. Secondly, users do not need to buy an extra expensive adapter.

Summarizing this section, WLAN looks very promising. The last hurdle to be taken for using WLAN as a backhaul is handover performance. To evaluate the performance of handovers in WLAN a handover test will be executed, of which the results will be discussed in the next section.

F. Fast Roaming

The handover performance of WLAN in terms of latency and packet loss is still unclear. Vendors often boast their capabilities and performance. In the original design of the IEEE 802.11 standard handover and roaming were not incorporated, even not to mention the combination with security algorithms. Only mid 2004 the layer-2 handover in combination with 802.1x was standardized in the 802.11i addendum. Recently vendors have started to implement one or both methods the standard prescribes. Currently Taskgroup R (TGr) is developing methods for fast roaming (layer-3). Meanwhile, vendors are implementing proprietary solutions for layer-3 roaming. In an extensive test both layer-2 and -3 handover will be dealt with. Vendors that were tested are Aruba, Cisco, Colubris, HP, Lancom, Proxim and Trapeze. The test is performed in cooperation with Lumiad, a company specialized in security and wireless networking.

Test set-up

A route was set-up through the hallway of the office building. During the course 4/5 access points (maybe less depending on the coverage) where several access points are passed (walking/running) in a same subnet and between 2 subnets. The security suites that are applied are: WPA-PSK with AES, WPA-802.1X and WPA2-802.1X Using a protocol analyzer (Airopeek/Ethereal) the roaming latency is measured (association and setting up master/session keys) with the mostly used client adapters (Broadcom, Intel, Atheros). At application level wireless VoIP (X-lite and dedicated phones) is used for measuring the end-to-end latency.

Results

The conclusion is made that the supporting infrastructure works fine; either centralized (thin access points like Airespace) or decentralized (thick access points). Qua performance there are no appealing differences between the two solutions. The choice for a specific architecture is thus based on other parameters, scalability, manageability and ease of deployment..

Fast handovers in WLAN can be performed when a number of design parameters are taken into account. First of all the network coverage of all access points should overlap very well, thereby avoiding black spots. As a guideline, the minimum signal strength should be between -60 and -70 dBm. Secondly, the roaming decision that is made in the client should be rather aggressive. Some clients have the tendency to stick with an access point for too long. As a result the signal strength reduces to a large extent, causing a large bit error rate.
Finally, by configuring parameters that control the active scanning phase (probing requests / responses) valuable ms can be gained. The key handshaking for security (802.1x) is not the major cause of handover latency, probing is. Scanning should only cover the channels used (probably 1,6 and 11) and furthermore reducing the scanning interval will save some time.

If these design specifications are taken into account handover times can be established between minimal 80 ms and maximal 300 ms. If not, things could really mess up. Handover times of multiple seconds are measured, resulting in drops of phone calls or TCP sessions. Layer-2 or Layer-3 handovers are almost equal in performance. In centralized networks handover performance is equal, as the centralized controller does not really perform layer-3 roaming, but simulates it. In decentralized networks layer-3 roaming introduces an extra step to be taken (tunnel set-up), increasing handover time only in the margin. In the table below, the roaming performance in terms of end-to-end latency is summarized.

	Atheros (Zero Config)	Intel (v.10 supplicant)
Median (80%)	100 ms	80 ms
Worst case	400 ms	300 ms
Best case	80 ms	68 ms

Table 1: Handover performance times using WPA2/802.1x and fixed channel deployment (ch.11)

With these results, the final technical hurdle for implementation of WLAN to fast-moving users has been overcome. As a result, there is no need to wait for WiMAX Today, proven technology based on the 802.11 protocol is sufficient in terms of throughput and QoS for providing value-added services.

III. Financial portfolio

This last section focuses on the financial aspects of broadband services on rail tracks. The business case is analyzed in terms of revenue streams and total cost of ownership (TCO).
As methodology the Net Present Value (NPV) analysis is performed to value the risk of infrastructure decisions. Two main scenarios are examined; a first one based on the deployment in the densely populated areas, and a second one based on a nationwide deployment.

Cost calculation

Scenario 1: densely populated areas

When a free market approach is taken, the consortium only invests in the most lucrative sections with most customers. In this case the investments are very moderate.
The Dutch rail network consists of 2809 km rails. A raw estimate is made that for providing services to 80 percent of the railway travelers 50% of all tracks should be covered with radio signals. Thus 1400 km of rails need to be covered with radio.

The transportation company has a large amount of rolling stock, i.e. 2675 carriages (including spare stock). These carriages form together 450 train sets (containing multiple carriages with 2-way driving capability). Once again the estimate is made that with 80 percent of all rolling stock 80 percent of the customers are reached. In this case 300 train sets are deployed with the needed devices and infrastructure.

Based on these parameters the cost calculation of the complete infrastructure and operation is determined. To deploy 802.11-based networks in the busiest parts of the Netherlands, an investment of 10.5 Million Euros is required [5]. This enables 80% of all railway travelers in the Netherlands to use broadband services in trains. When every railway track is deployed with radio coverage, twice the investment is required. This investment does not return twice the revenues, because 80% all travelers are already reached with 50% of all tracks. Thus, from a commercial point of view is the scenario preferred in which only the rail tracks with most passengers are covered. However from a social point of view, the second scenario is preferred. In order to attract more people to use public transport, infrastructure should be deployed nationwide.

Scenario 2: nationwide

Making the business case fly for broadband services is not a problem on the busiest sections in the Netherlands. However for the less traveled sections of the Dutch railway network revenues are expected to be lower. In order to connect all travelers (broadband for everyone, just like telephony), about twice the cost is made in infrastructure and operational expenditure. The government should subsidize part of the infrastructure as part of the vision to make public transport more attractive. Governments should subsidize innovative wireless services in trains, because of the following argument. Mobility in the Netherlands is a tricky business. The government invests billions of dollars in broadening motorways in order to reduce congestion. In that footlight; with little investment in innovative internet services public transport is made more attractive compared to car use. The availability of these services may very well be the turning point to choose for public transport for a lot of users.

The capital expenditure is estimated on € 20 million with an operational expenditure of € 1.000.000 per year.

Revenues

More than 1 million people in the Netherlands make use of railway services everyday. Eighty percent of all passengers implies the percentage of travelers that NS transfers nationwide per day in the busiest areas of the Netherlands considered in scenario 1. Of this target group 15% carries a WiFi enabled device, of which 5% will actually use their device for wireless services. One can think of many different ways to price sessions, e.g. coupled with a ticket, or with the time services are actually used. An average of 2.50 per session is used in the calculation. To take account for weekends and holidays, only 250 days are effectively calculated per year

In terms of revenues many researchers today underestimate the role of WiFi in the coming 3 years. WiFi will be incorporated in many devices, not only laptops, but also mobile phones, PDA's and gaming devices (e.g. Playstation portable). In 2010 fifty percent of all travelers will be WiFi enabled. When the estimate is made, that 5-15% of the travelers that are WiFi enabled actually use their devices, the business case is very lucrative.

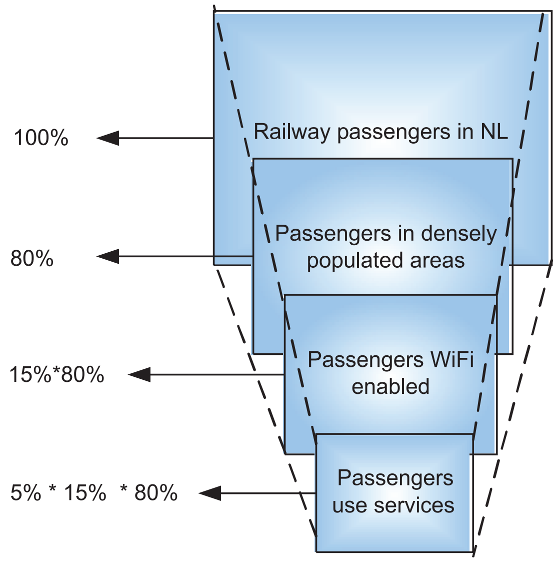

Figure 3: estimate of percentage of railway travelers that will actually use broadband services in 2007

Net-Present Value calculation

Infrastructure investment decisions are usually supported by means of the so-called net present value (NPV) analysis. NPV compares the value of a Euro today to the value of that same Euro in the future, taking inflation and returns into account. This analysis states that 10 euros received now is worth more than 10 euros received later. If the NPV of a prospective project is positive, it should be accepted. However, if NPV is negative, the project should probably be rejected because cash flows will also be negative.

$$NPV = \sum_{t=1}^{T} \frac{C_t}{(1+r)^t} - C_0$$

In this equation are: C_t : cashflow at year t,
r: cost of capital, and C_0 : present value.

The NPV calculation is presented in Annex 1. In case of scenario one the investment is staged in two subsequent phases. The specification of costs used, is found in Annex 2. In the overview probabilities are given to the uncertainty concerning how many travelers are WiFi enabled and how many users will actually make use of services.

The NPV analysis rigorously gives a GO advice; the business case is definitely a no-brainer. In case of a deployment on sections with most travelers a return-on-investment is obtained within 2 years. In five years an estimate net-present value of 38 Million Euros is calculated.

IV. Conclusion

Broadband applications in trains based on a two-tiered architecture are a cheap tool for increasing mobility reducing congestion on motorways, because it attracts people to public transport who are currently using other modalities.
WLAN networks based on the IEEE standard (not standard WiFi) provide the best solution for the backhaul in terms of performance and cost.
To be really an attractive alternative for car use, services should be available on all rail tracks, also in non-profitable areas. The government might help a hand here, providing subsidies.
Besides, compare the amount of investments made for increasing traffic capacity (asphalt) and reducing CO_2 emission. In that footlight it is plausible that the federal government should also subsidize these kinds of services.

Biographies

Ir. H.B.J. ter Harmsel
Hermen ter Harmsel received his MSc degree in System Engineering, Policy Analysis and Management from the Technical University in Delft in 2003 after doing the thesis project on the market development of location-based services. Furthermore, he obtained a MSc. degree in Electrical engineering from the TU in Delft in 2006 after finishing his thesis research on broadband wireless applications and services in railway environments

Prof.dr.ir. N.H.G. Baken
Professor Baken currently holds a part-time chair in the Telecommunications Department at Delft University of Technology alongside his primary position as Chief Architect for The Royal KPN, the Dutch incumbent operator in the Netherlands. His main interest concerns broadband networks and services, dealing with a broad range of aspects such as fiber access infrastructures, fixed-mobile convergence, services, operations, financial strategies such as real option analysis, managerial complexity and regulations. Given this spectrum, he has been asked to advice the Dutch government on the matter of broadband and the roll out of fiber to the home in the national expert group broadband and in the Andriessen committee (former minister of Economic Affairs) to deal with the FTTH for Amsterdam and the Hague. He finished Gymnasium ß in 1973 and graduated, cum laude, in mathematics at Eindhoven University of Technology in 1981. He has published over 30 papers, holds several patents and won several prizes for his scientific work; for example, the Dr Neher Laboratory prize (yearly prize for the most outstanding researcher). He received his Ph.D. Thesis from the Delft University of Technology at the department of Electrical Engineering, working with Professor H. Blok and Professor A. T. de Hoop.

Ir. H.M. Meijsen, tba
Herman graduated at the Delft University Technology in 1980 and started his career as a services developer in the telecommunications industry. He entered Royal KPN, the Dutch incumbent telecommunications operator in 1988. In 2002 he started his own consultancy venture and entered Movares (formerly NS, Holland Railconsult), the leading consultancy company providing innovative solutions for infrastructure and transportation systems. He is fully versed in systems engineering for telecommunication networks, network architecture and capacity planning, first-implementation techniques, as well as project inauguration, definition and budgeting. As operational manager, he has been responsible for network architecture and development resulting in the networks being ready for operational service in the Netherlands and in Europe. Besides that he has broad experience as an operational manager in process analysis, change management and process implementation as well as project management.

Ing. E.B.M van Boven
Edgar van Boven studied electronics and IT at the Technical Highschool in Vlissingen. Though tempted to start an adventurous life as a jazz pianist, he graduated in 1987. After military service as a sergeant in a telecommunications battalion, he entered KPN. Until today public telephony has dominated his career from various viewpoints starting with hardware and software engineering, via operational network planning to architecture and programme management. In the late-1990s, he started to work on the evolution to voice over packet in the former Unisource Business Networks environment within KPN. Since 2001, he has also been guest lecturer at the Delft Technical University. Today he is working in the area of fixed mobile convergence.

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References

[1] Rapport commissie Nouwen; Nationaal Platform - Anders Betalen voor Mobiliteit, mei 2005
[2] Streetlight®; www.streetlight.nl
[3] Belk, J.; Why MAX? *A Wireless Primer and Discussion on Wireless Reality;* Qualcomm white-paper; 2005
[4] Baken, N.H.G., Van Boven, E; Den Hartog, F.T.H. and Hekmat, R.; *A Four-Tiered Hierarchy in a Converged Fixed-Mobile Architecture, Enabling Personal Networks*; KPN Telecom & TU Delft; 2005.
[5] Harmsel, H.B.J., Baken, N.H.G: *Broadband Applications on railway tracks; the business case for fast roaming WLAN*; master thesis; TU Delft and Movares, Netherlands, may 2006

The new broadband world: back to circuits again?!

Nico Baken, Martijn van Riet, Joost Warners en Gerard Deurwater

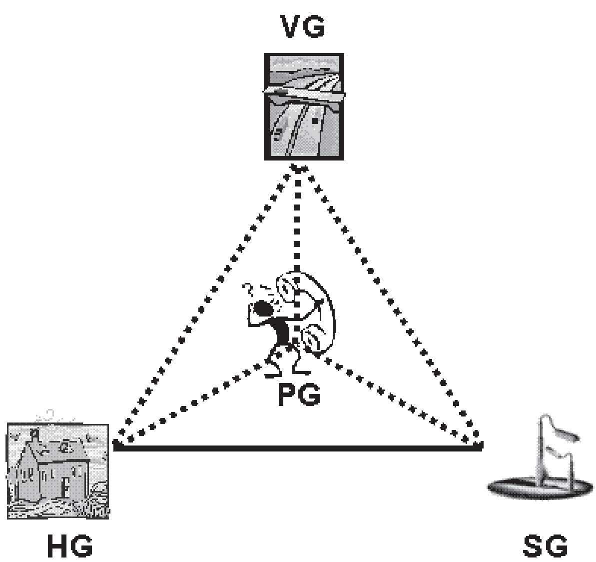
Abstract
Three major trends; an ever growing need for bandwidth, an increasing demand for real-time high QoS broadband Value Added Services and the tendency to enjoy nearly all of these services wirelessly, lead us to reconsider the benefits of packet-switched networks and inspire us to look for alternative network options. A revolutionary approach is to revert to circuit switching in casu to all-optical switching and routing, in order to obtain highly efficient routing and fast transmission. In this paper we explore the possibilities and requirements with regard to this solution.

I. Introduction
One of the main drivers for developing and introducing packet switched networks was the scarcity of bandwidth. Packet switched, connectionless networks indeed seem to enable a much more efficient usage of available bandwidth. Nowadays, telecommunication services become more and more ubiquitous, and users increasingly want access anywhere, anytime. This implies that the traffic volumes are increasing enormously and networks keep expanding, facing us with many new challenges. Besides the challenge to realize ubiquitous wireless access, another important challenge is the ever-increasing demand for delivering quality of service (QoS) using IP networks. However, precisely this worldwide advocated protocol is intrinsically not suited to guarantee the required quality! Especially when the complexity of network increases and the number of hops increases with it, this is the case. Thus, routing of traffic becomes complex and time consuming, potentially growing to unacceptable heights. On the other hand, the development in the optical world enables enormous transmission speeds, while the number of lambdas per fiber is increasing as well. Thus we migrate from an era of bandwidth scarcity to one of bandwidth abundance. So why not go back to a connection-oriented, circuit-switched type of network, making life easier and guaranteeing defined levels of QoS?! To ensure fast routing of traffic, an all-optical solution would be ideal. Having a proper "lambda-converter" might imply such a network once again as a better solution than the current incumbents are opting for right now with billions of investments! Obviously, our suggestion therefore would be worthwhile to consider and study in depth.

In this paper we outline the concept and explore the functionality such a converter requires and assess the quantitative possibilities of such a revolutionary network.

We show that millions of fixed access nodes can be uniquely and mutually connected given a suitable hierarchical fiber topology, under seemingly reaso-

Figure 1. User-centric representation of the telecommunication hierarchy. Fixed links are represented by drawn lines, wireless links by dotted lines.



nable requirements with regard to the number of lambdas per fiber. The access nodes are also referred to as the 'nerve nodes' in the fixed Telecom Mycelium [4]. If the nerve node is not the first source or end destination, then the first/last hop to the true source or end destination respectively will be executed wirelessly. The radio hop can be accommodated by all kind of radio access technologies involving e.g. *ad hoc* and *mesh* networks. In the nerve nodes, the fixed network is terminated by gateways. See also Figure 1. We distinguish Home (or Office) gateways and Street-gateways (think of street cabinets or more general streetfurniture, see also www.streetlight.nl). Personal- and Vehicle-gateways connect to these fixed gateways, see also [6] and [7]. An overview of the communicating entities at the source and end destinations is presented in [5].

NB. A note on terminology: we will freely use the terms lambda, colour, wavelength to have more or less the same meaning.

II. Limits to growth?

Historically, a typical network used to be connection-oriented: in a circuit-switched network, a circuit is established between a given source A and a destination B, and the capacity of this circuit is fully reserved for traffic between A and B. The routing of the traffic is static. From the viewpoint of efficient usage of resources, this may not be adequate. Most likely, a substantial fraction of the time, even when the 'call is up', there will be no traffic between A and B (intuitively one might think of the silences during a telephone conversation). In a world where capacity was scarce, solutions were required and these were found by developing packet-switched networks. In such a network, 'pieces of traffic' (packets) with different sources and destinations are handled via one and the same link, requiring capacity only when actual traffic is sent. Intuitively, this indeed leads to a more efficient usage of capacity. On the other hand, this means that for each of the packets, an analysis has to be carried out to determine the next (intermediate) 'hop'. Since it is not required that any two packets with the same source and destination follow the same route, this type of networks is also referred to as 'connectionless'.

Internet routing

The internet is the perfect example of a network in which the benefits of the connectionless network are made practical. However, the internet was never designed for offering service guarantees; it is in fact a chaotic network in which each packet separately tries to find its way. If one route is blocked, another is sought, and if a packet gets lost, it is retransmitted. With the ever-continuing growth of the internet, simply expanding capacity may not be sufficient in the longer term [2]. Routing becomes a more and more time-consuming mechanism, and with this development, more and more expensive. Even more so when the Border Gateway Protocol (BGP) is active. This protocol determines the routing between the sub-networks (autonomous systems) of the internet. It is not based on shortest path algorithms, but takes into account the agreements between various ISPs. Experts claim that the BGP already is reaching its limits [2], especially when also different service classes have to be taken into account (in order to accommodate service differentation between various services).

Since routing now has to satisfy numerous criteria (as opposed to a shortest path algorithm where only one criterion has to be satisfied), the routing problem turns into a 'difficult' (NP-complete) problem. For such problems the calculation time increases exponentially with the problem size. Extensive research is currently carried out to obtain exact solutions for the multi-criteria routing problem. SAMCRA (Self Adapting Multiple Constraints Routing Algorithm) is an example of an algorithm in which QoS criteria can be handled, while the computation time remains acceptable. This is one of the options for future internet routing.

However, for the protocols that are currently used, such a routing algorithm is not yet possible. For example, using MPLS, circuits[1] are simulated by defining LSPs (Label Switched Paths). In order to improve QoS, traffic is divided into various service classes. This however does not offer a solution to the complex and inefficient routing sketched earlier.

1 Indeed, this confirms the tendency to go back to circuits rather than packet-switching!

Trends in capacity expansion

Another relevant development is the fact that transmission speeds are ever increasing. At this moment in time, 16×2.5 Gbps DWDM[2] links per fibre are common, while more advanced variants of DWDM are available: DWDM systems allowing eighty wavelengths (lambdas) can be readily obtained. It is important to observe that the primary driver for using packet-switched networks, the efficient usage of resources, becomes less relevant when resources are infinite. The limit of the development of resources can be defined as the situation in which circuits can be set-up between any two sources and destinations on the level of (optical) transmission.

The developments sketched above, lead us to the conclusion that the limits to the growth of the internet are imposed by the increasing complexity of the routing algorithms, rather than by a scarcity of capacity on the fibre level!

Given this conclusion, let us now construct a scenario, building on a different routing mechanism.

III. An all-optical solution

Nothing travels as fast as light, therefore the ideal situation to transmit data is using light. In (tele-)communication networks, light is obviously already deployed to send data through the fibres, but on the nodes often manipulation at the electrical level is required. This transformation from light to electrical signals, and back to light again, is time-intensive. If all manipulation could be done in the optical domain, enormous savings of time could be realized. Currently, integrated optical chips (IOCs) can operate at a speed up to 1 Gbps [8]. However, theoretically this speed could be increased to 100 Gbps, when the technology matures [1].

This principle of fully optical switching is elaborated upon in the following sections. The basic idea consists of a network architecture, based on connected fibre-rings. On this architecture, end-to-end optical circuits are defined. The transmission of the signals in each ring is based on DWDM-like technology. On the nodes connecting two rings, wavelengths are cross-connected and if necessary, converted. While we realize that such a situation is not yet entirely possible, the current developments are such that it may turn out to be feasible in the future.

IV. High-level analysis of the all-optical solution

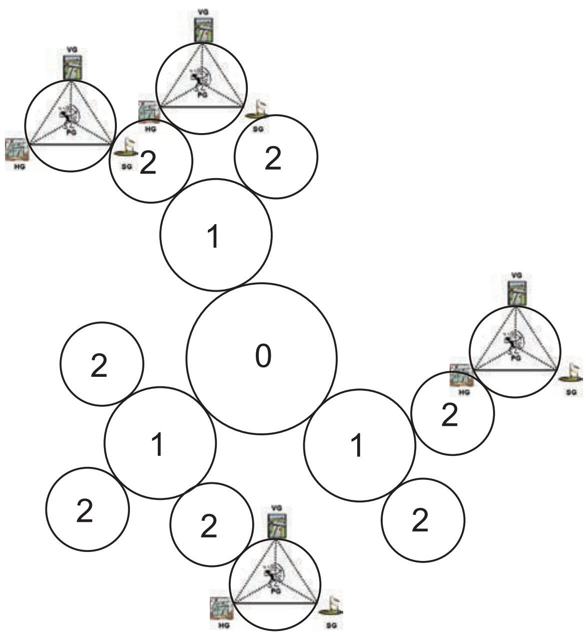
We require a network, in which the route between any source and destination can be defined by a lightpath. Depending on the depth of the hierarchy of fibre rings, the number of lambdas per fibre, and the number of fibres per duct, an upper bound M can be computed on the number of customers that can be mutually connected in this way. We are interested in developing criteria, under which M can be large enough in order to connect all nerve nodes in, for example, a country like the Netherlands. Initially, we restrict ourselves to quantitative considerations. Further on, we take a look at some technical implications.

Definitions and notation

Let us consider a hierarchical network, consisting of interconnected rings, see for an example Figure 2. The depth of the hierarchy H is defined as the number of rings that has to be traversed from the central ring (indicated by '0') to an access-ring, illustrated by the nerve nodes as introduced before, excluding the central ring.

Traffic between source A and destination B is routed via a *lightpath*. A lightpath is defined as a

Figure 2 Illustration of a network hierarchy of depth 3.



2 DWDM = Dense Wave Division Multiplexing.

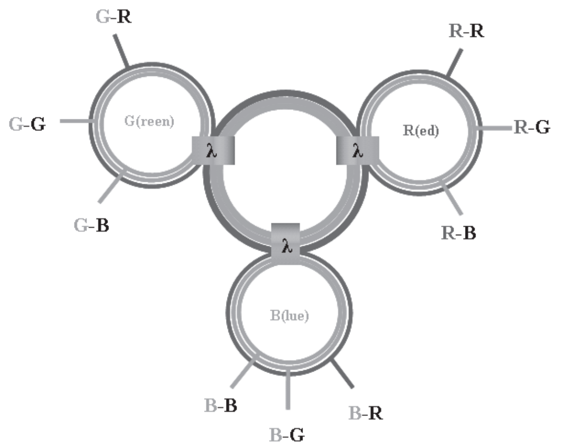


Figure 3 Example network with 9 nerve nodes.

series of lambda("λ")-fibre combinations. For now, we leave the *length* of this series unspecified.

At the nodes where two fibre-rings connect, a piece of equipment is installed that can multiplex and cross-connect the lambdas. We call this equipment the "λ-*converter*". Before we investigate its required functionality, we distinguish between two fully optical scenarios:

1. A-priori lightpaths between *any pair* of nerve nodes.
2. Lightpaths between any access point and the central ring.

Scenario 1

In this scenario there truly is bandwidth abundance, allowing us to define a lightpath between any pair of nerve nodes. The length of a lightpath is then equal to the number of rings that is passed between source and destination, in this case (at most) $2H+1$.The required number of unique lightpaths is proportional to the number of nerve nodes squared! In this scenario, the intelligence required from the λ-*converter* is limited.

To provide some intuition on the resources required in this scenario, let us consider a small example. Suppose we have a situation in which three rings are connected to one central ring; each of the rings consists of a single fibre. Attached to each of the three de-central rings are three access-points, resulting in a total of 9 access-points. If each access-point must be connected to all eight other nerve nodes, with a capacity of x kbps (independent of whether it is actually used), then each access point requires a capacity of 8x kbps. The required capacity in the network is in the order of 72x kbps[3].

Obviously, many refinements could be made, for example, not all links require capacity on the central ring. The important notion is however that in any case the central ring requires a capacity of the order of the number of nerve nodes squared. Therefore, in a situation where the number of nerve nodes is large, say 10^7, the required capacity is something like $10^{14} \times x$ kbps. Even when x is 'small' this is a seemingly unrealistic requirement, so we opt for the other scenario.

Scenario 2

In this scenario, let us start with the assumption that enough capacity is available, to provide a unique lightpath between the *central ring* and any nerve node. The advantage is that the number of unique lightpaths we start with, is linear in the number of nerve nodes. In this situation the length of a lightpath equals H. In this scenario additional functionality from the λ-*converter* is required, as we will see later.

We consider the impact on our example network and approach the calculation from a different viewpoint. First, we assume that on each ring, C lambdas are available (for the time being, we do not need to specify its corresponding capacity). Attached to each ring are at most C rings (or nerve nodes) lower in the hierarchy. The hierarchically lower ring is assigned a colour (part of the optical spectrum). For example, see again Figure 3, the rings R, G and B are assigned the colours Red, Green and Blue.

If data is transmitted from access-point G-G to access-point R-G, the routing is done as follows:

1. Data is sent through ring G, via lambda G
2. The λ-*converter* on ring G reads from the header that the data has as destination: R-G. Since the destination is on ring R, the λ-*converter* converts the data into wavelength R on the central ring.
3. The λ-*converter* on ring R takes wavelength R and reads that part of the signal has destination G.

3 If N nerve nodes are present, $2 \times \binom{N}{2}$ links must be facilitated. The multiplication by 2 is due to the assumption that up- and downlink traffic must be facilitated.

4. It converts the appropriate part of the signal to wavelength G on ring R; subsequently access-point R-G receives the wavelength.

Implicitly, this routing mechanism puts a number of requirements on the λ-*converter*. These will be investigated later on. First, we consider a number of quantitative implications of this scenario.

Quantitative analysis
The maximal number of access-points can be calculated via

$$M = C^{H+1} \quad (1)$$

where C is the number of lambdas per fibre and H the depth of the network hierarchy. To get an impression of the orders of magnitude involved: if a DWDM system offers 16 lambdas per fibre, and the depth of the network hierarchy is 3 then M = 65.536.

Note that M in fact equals the number of unique lightpaths of length H+1. The construction implies that the route between access-point and the central rings is unique for each access-point.

The following remarks apply:
1. The number of access-points is maximized if to each ring on level h, exactly C rings on level h+1 are attached.
2. In the central ring, traffic of at most C^H customers is carried in 1 lambda.
3. It is implicitly assumed that the λ-*converter* can de-mulitplex traffic: a lambda on a hierarchically higher ring is converted to different lambdas on the hierarchically lower ring.

Finally, let us show that (1) can be generalized in a straightforward manner to take into account the number of fibres per ring, which we note by V:

$$M = \left(C \times \frac{V}{2}\right)^{H+1} \quad (2)$$

From the rough derivation it is clear, that in order to enable unique coding of large quantities of nerve nodes (nerve nodes), C and/or H need to be big. Note that in case of a 'large C' remark 1 leads to unrealistic physical requirements, since it is not realistic to attach hundreds of subrings to one ring.

So let us refine our calculations somewhat. We restrict the number of rings that can be connected to a hierarchically higher ring. The number of hierarchically lower rings, directly attached to a ring on level h, is noted as A_h .

Then the formula for M can be adjusted as follows:

$$M = \prod_{h=0}^{H-1} A_h \times \left(C \times \left(\frac{V}{2}\right)\right).$$

Note that if A_h is small in comparison to C, remark 2 above should be adjusted, since there are more wavelengths available at the hierarchically higher rings.
The number of rings R at hierarchical level P, $P \geq 1$, equals: $\prod_{h=0}^{P-1} A_h$.

This implies that the number of nerve nodes requiring capacity on a ring at level P is:

$$M = \prod_{h=P}^{H-1} A_h \times C \times \frac{V}{2}.$$

This, in turn, implies that the available capacity per access point on a ring at level P equals:

$$\frac{cap(\lambda)}{\prod_{h=P}^{H-1} A_h},$$

where cap(λ) denotes the capacity of a single lambda.

For example, in a network with a single central ring, in which eight hierarchically lower rings are attached to any ring, with depth of hierarchy 4, C = 64 (lambdas per fibre) and V = 96 (fibres per duct), the number of unique lightpaths equals: (1 × 8 × 8 × 8 × 8) × (64 × 96/2) = $12{,}5 \times 10^6$.

Connecting these $12{,}5 \times 10^6$ nerve nodes, all requiring an access speed of 10 Mbps, the required capacity in the central ring equals $12{,}5 \times 10^6 \times 10$ Mbps = 125 Tbps. Such a capacity does not appear entirely unrealistic. It is interesting to note that this amount of nerve nodes is enough to cover a country like the Netherlands: given an area of 40.000 kilometers squared, this implies on average 100 to 1000 nerve nodes per square kilometer, which in turn corresponds to a grid of 100 × 100 meters in rural areas and a grid of 30 × 30 meters in urban areas.

Note that the (theoretical) capacity of the hierarchically lower rings is of the same order of magnitude, however due to the lack of statistical multiplexing and lack of effects of overbooking, the rings may have a (sometimes extremely) low fill grade - this also depends on the implementation of the λ-*converter*, as we will see in the next section.

V. Functionalities of the lambda-converter

Hitherto, we have considered the λ-*converter* as a black box, implicitly assuming that it is capable of any functionality we required for our purposes. However, it will be clear by now, that in order to realize a fully optical network as sketched above in the 2nd scenario, the λ-*converter* requires sophisticated features. In this paragraph we go into further detail as to these features and also assess the technical feasibility.

Multiplexing and demultiplexing

The λ-*converter* must be able to convert a number of incoming wavelengths into a single outgoing wavelength. This applies to wavelengths that are transmitted to the hierarchically higher rings. On the other hand, for transmission in the other direction, the wavelength must be unravelled into several outgoing wavelengths.

Micro-burst

The joining of several traffic flows in a single outgoing wavelength, should be carried out in the time domain. Strictly speaking, this is not analogous to multiplexing in the electrical domain. To facilitate the multiplexing in the time domain in the higher levels of the network (where the traffic of a large number of nerve nodes is handled), large traffic volumes need to be transmitted in very short time intervals. We call this 'micro-bursts'. See Figure 5. The brief and extremely high transmission peaks, must be converted in sequence on the outgoing wavelength. This requires dynamic synchronization of the peaks, in the time scale of micro- and milliseconds. Moreover, it is required to be able to capture the optical information in a buffer.

Figure 4: The λ-converter as a (de-)multiplexer

Figure 5: Demultiplexing of micro-bursts by the λ-converter

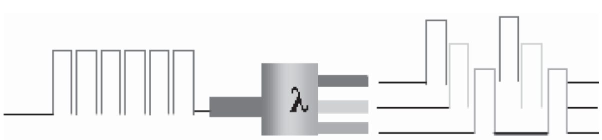


Figure 6: By expanding the micro-bursts, the traffic flows is of a more continuous nature at a lower bitrate.

Note that also the hierarchically lower λ-*converters* and even the customor premises equipment should be able to handle these microbursts. In practice this implies that the equipment will receive data during a very short period of time, while during a large fraction of the time nothing happens. This suggests inefficient use of available resources; this need not be a problem.

Time compression/expansion

A more sophisticated extension of the functionality is to spread the peaks over a larger time interval, when transferring from hierarchically higher to lower rings The λ-*converter* needs to handle a smaller bitrate during a longer period of time. See also Figure 6. By expanding the micro-bursts, the traffic flow is of a more continuous nature at a lower bitrate. The λ-*converter* needs to be equipped with time-compression and -expansion possibilities.

To the best of our knowledge, the combination of the required functionality with regard to micro-bursts, dynamic synchronisation and optical buffering is currently not available in the all-optical domain. On the other hand, development is ongoing in these fields and therefore the scenario may turn out to be feasible in the not so far future.

VI. Concluding remarks

As we have seen three major trends, firstly an ever growing need for bandwidth, secondly an increasing demand for real-time high QoS broadband Value Added Services and thirdly thentendency to enjoy nearly all of these services wirelessly, lead us to reconsider the benefits of packet-switched networks and inspire us to look for alternative network options.

A revolutionary approach is to revert to circuit switching in casu to all-optical switching and routing, in order to obtain highly efficient routing and fast transmission. The requirements of the equipment involved are not yet feasible, however it appears that in the future the requirements could be met, given the intensity of research in the area of optical networks and Integrated Optics. If we combine our concept with the third trend, i.e. the tendency towards wireless access for the last meters in the pico- or micro-cells to enable the consummation of all services wirelessly, the contours of the future network become clear. We see an optical, circuit switched fixed Telecom Mycelium, of which the nerve nodes at the end of the Mycelium threads are circumvented by radio pico-and micro-cells using *ad hoc* or *mesh* network topologies.

Given the logic, impact, advantages and anticipation on the current and future trends, we fully believe that our suggestion would be more than worthwhile to consider and be studied in depth. The concept can be gradually implemented starting for core and migrating via metro networks to the access and home-/office-networks. In fact, our concept could be envisaged as the next step of the Negroponte Switch [3], say the *Baken Switch*.

For the shorter term, all-optical routing and switching is already efficient when large amounts of data have to be transmitted. For the smaller volumes, the conversion to the electrical level still has to be made.

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References

[1] Doorbraak Cobra in volledig optische data-communicatie - http://www.bits-chips.nl/info.asp?mode=&ac=view&inf_id=783
[2] Delft Integraal, 2-2004, "Delfts Algoritme moet Internet verkeersinfarct redden",pag. 17-20Kl
[3] Negroponte, N. (1995). Being Digital. Knopf. (Vintage Books, ISBN 0679762906
[4] Baken, N.H.G., Van Boven, E; Den Hartog, F.T.H. and Hekmat, R.; A Four-Tiered Hierarchy in a Converged Fixed-Mobile Architecture, Enabling Personal Networks; KPN Telecom & TU Delft; sept 2005.
[5] Virtual Mobility, Enabling Multi-Dimensional Life, FITCE 2005, ept, Vienna, Baken et al
[6] Multiple Wireless Protocol Advertising System, Enabling Automatic Access Selection and Local Services, FITCE 2006, Skief Houben et al.
[7] Broadband Services on Rail Tracks, FITCE 2006, Hermen ter Harmsel et al.
[8] Computational Modelling of Integrated Optical Waveguides, PhD Thesis N. Baken, okt 1990, Plantijn Rotterdam, ISBN 9072125231

Scanning our past from the Netherlands
early galactic radio astronomy at Kootwijk and some consequential developments

Bob van Loon, Ari Hin

During World War II, Prof. Dr J. H. Oort (Fig. 1), the famous Dutch astronomer and discoverer of the origin of our comets, was living in the countryside of The Netherlands. At that time it was an occupied country. He decided one day to ride his bicycle to visit the Observatory at Leiden University, which in fact had been closed for some time.
Halfway on this 120-km trip to Leiden, which is near the North Sea coast of The Netherlands, he got a flat tire and was forced to interrupt his trip at the residence of one of his promising students. With this student, the future Prof. Dr. H. C. van de Hulst (Fig. 2), he discussed potential new means, in addition to the well-known optical methods, to observe gaseous clouds in the galaxy.

Hydrogen atom emissions

At that time Karl Jansky and Grote Reber had already made their observations of radio noise emitted from the sun and from other sources within our galaxy, in 1932 and 1938, respectively. In 1944, Oort had already recognized the importance of radio waves for astronomical observations, and he quietly arranged a colloquium on radio waves from space at the Leiden Observatory. The young student H. C. van de Hulst explained to the limited audience the results of his study that neutral hydrogen atoms in the universe would emit a spectral line in the radio spectrum corresponding to a wavelength of 21.2 cm (or a rest frequency: 1420.4057 MHz), resulting from changes of the electron spin within hydrogen atoms.
Van de Hulst suggested that by using the Doppler principle, this effect could be a perfect means to determine the velocities in the structures of the galaxy. It was probably the first time that professional astronomers discussed the possibilities of radio astronomy. In the following postwar years, radio astronomy in Australia, England, and the United States led to many fascinating discoveries.

The dish

Building a large radio telescope in The Netherlands just after the war, with a diameter of some 25 m necessary for the detection of weak signals, was financially not feasible. How

Fig. 1. Prof. Dr. J. H. Oort, the famous Dutch astronomer and discoverer of the origin of comets.

Fig. 2. Prof. Dr. H. van de Hulst first concluded that neutral hydrogen atoms in the universe would emit a spectral line in the radio spectrum, corresponding to a wavelength of 21.2 cm.

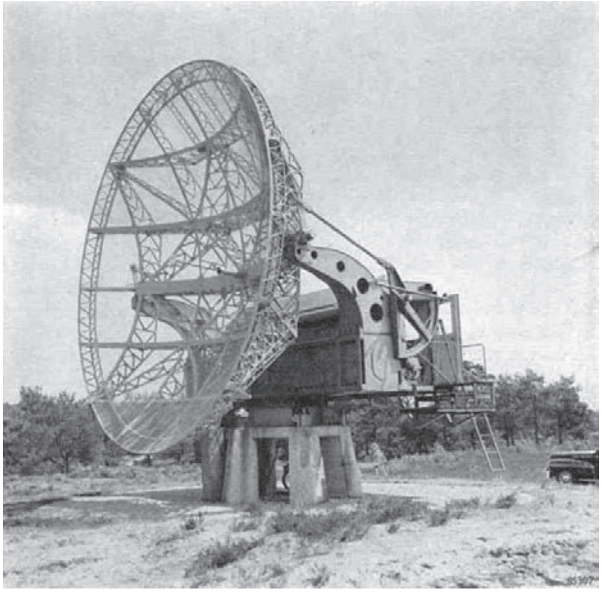

Fig. 3. Wurzburg antenna at Kootwijk, The Netherlands.

Fig. 4. Prof. Dr. C. A. Muller was in charge of the construction of the receiving station for the hydrogen-line experiment.

ever, along the coast of the European continent a few of the 7.5-m Wurzburg antennas, which had been part of a German radar chain, were still available (Fig. 3). Some of them were already in use for the study of radio propagation in the ionosphere. One of these antennas was made available to the new Stichting Radiostraling van Zon en Melkweg (Foundation for Radio Emission From the Sun and Milky Way, later The Netherlands Foundation for Radio Astronomy), a cooperation of universities and industry, with Oort being their first chairman. At that time, obviously, one had hoped to observe radio waves from only our immediate "neighborhood," e.g., the sun and the Milky Way at most. There was no expectation at that time of detecting radio waves from the farthest corners of the universe, as is common practice today.
The construction of a receiving station for the hydrogen-line experiment was started for practical reasons at Kootwijk Radio, in the center of The Netherlands, where a station of the Dutch PTT was located. This was a remote area, but uncomfortably close to high-power transmitting antennas. Halfway into the program to construct this system, a fire unfortunately delayed progress and forced the small crew, now with C. A. Muller (Fig. 4) in charge, to start all over again.

Worldwide efforts

In the meantime, based on the prediction of van de Hulst, a small community of radio astronomers — H. I. Ewen and G. M. Purcell at Harvard University, Cambridge, MA, as well as W. N. Christiansen and J. V. Hindman in Australia — were working on an identical project, in mutual cooperation and exchange of ideas.
To satisfy the need for high sensitivity, a Dicke-type receiver was used, in which the (second) local oscillator frequency is periodically switched to a frequency corresponding to an adjacent frequency channel as reference. Comparing both signals by a synchronous detection system could indicate the presence of very weak signals. The presence of emissions from hydrogen clouds was confirmed on 11 May 1951, at approximately the predicted frequency, when the antenna was directed toward the Cygnus region. The result of the first survey is clearly shown in the depicted graph by manual tracking of that Cygnus area, corrected once every 2 min (Fig. 5). Actually, some six weeks earlier, Ewen of Harvard had already arrived at the same conclusion that detected the presence of the interstellar emissions by hydrogen, and Christiansen in Australia arrived at the same result a couple of weeks later.
These radio receivers turned out to be very effective instruments for astronomers, as for the first time it allowed the researchers not only to determine the position and the intensity, but in a later stage also the actual radial velocity component of neutral hydrogen clouds within the Milky Way.

Kootwijk measurements

In 1954, nearly full coverage of the Milky Way could be established by a coordinated effort of the three parties, each observing their specific "visible" section from their continent (Fig. 6).
The relative accuracy of the Kootwijk measurement corresponded at that time to approximately 1 °K.

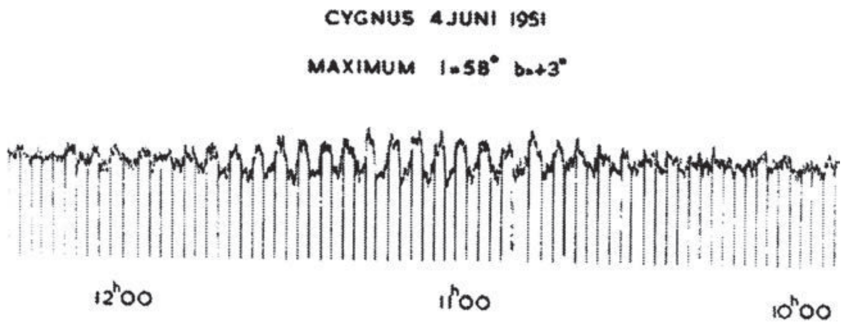

Fig. 5. One of the first hydrogen line observations for a drift curve through the Cygnus region.

The tangential velocity component in relation to the center of the galaxy was still in discussion at that time, but it was clear that a spiral structure of the Milky Way in conformance with the optical observations of other galaxies was most likely.

The results of the Kootwijk measurements were a boost for the development of a new astronomical center in Dwingeloo, in the northern part of The Netherlands. The main instrument in Dwingeloo was a single paraboloid reflector with a diameter of 25 m. It was officially put into operation in 1956. The development of radio telescopes had started.

Radio interferometry matures

During the second half of the 20th century, radio interferometry became a standard technique in radio astronomy besides the "classical" single-dish instruments. In Westerbork, not far from Dwingeloo, an earth-rotation synthesis interferometer telescope was put into operation in 1970. This telescope consists of fourteen 25-m paraboloids on an east–west baseline of 3 km. The angular resolution achieved by this instrument corresponds with that of a single-dish instrument of 3 km diameter. A further development was that of very long baseline interferometry: signals from cosmic origin are received by telescopes separated by even more than several thousands of kilometers, i.e., located in different continents and even located in space. These signals are later correlated with each other to produce a single image with an angular resolution corresponding to that of an instrument of the dimensions of the longest distance in the network. The radio observatory at Dwingeloo hosts the European correlator center.

Thus, Oort, van de Hulst, and Muller started a promising tradition, adding new wisdom to noisy cosmic signals.

Where does the state of the art stand today? The latest development is the LOFAR project, a very widely distributed antenna system that has been recently started and will be finalized in 2006. This system will cover an area of approximately 350 km in diameter and uses direct fiberglass communication lines to its center.

Fig. 6. Artist's illustration of the galactic system as seen from the north galactic pole, prepared from the 21-cm line observations by The Netherlands Foundation for Radio Astronomy of Leiden University and the Division of Radiophysics Common Wealth Scientific and Industrial Research Organization, Sydney, Australia. The density contrasts are accentuated for better perception.