Skief Houben, Nico Baken, Philippe Hervé and Rob Smets

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

We examined efficiency within wireless access options for mobile devices and discovered that a classic pitfall is revisited. As with the proliferation of services in incumbents' portfolios, leading to a number of co-existing so-called 'stove-pipes', we see an isomorphic phenomenon evolving in multimodal mobile devices, leading to an inefficient development of vertical stack technical solutions for each different mode. For the first time we found the optimal technical and commercial fit, i.e. between the internal device solution and the external service provider solution respectively, with tremendous benefits for the end user. Migration from vertical towards horizontal solutions, with tilting on device level, not only decreases costs but also hugely increases the flexibility for the introduction of new customised solutions. This article outlines a unique technology called XAS that enables automatic access selection for a requested service, based on qualifiers such as available bandwidth, QoS offered and connection costs. Clever implementation of this system will extend commercial utilisation further than just access selection. This system will also enhance the performance of existing devices in terms of stand-by time and security. In addition, it will open vast opportunities to introduce new and exciting services based on the location of the user. The solution outlined is not merely a theoretical exercise, but has already been built in a realistic pre-commercial demonstrator with which promising results have been obtained. Lucent Technologies has filed a patent for the system concept.

This article was presented at the 45th FITCE Congress which took place in Athens, 30 August – 2 September 2006. It is reproduced here by kind permission of FITCE.

The Authors: Skief Houben and Nico Baken are with Delft University, and Philippe Hervé and Rob Smets are with Lucent Technologies.

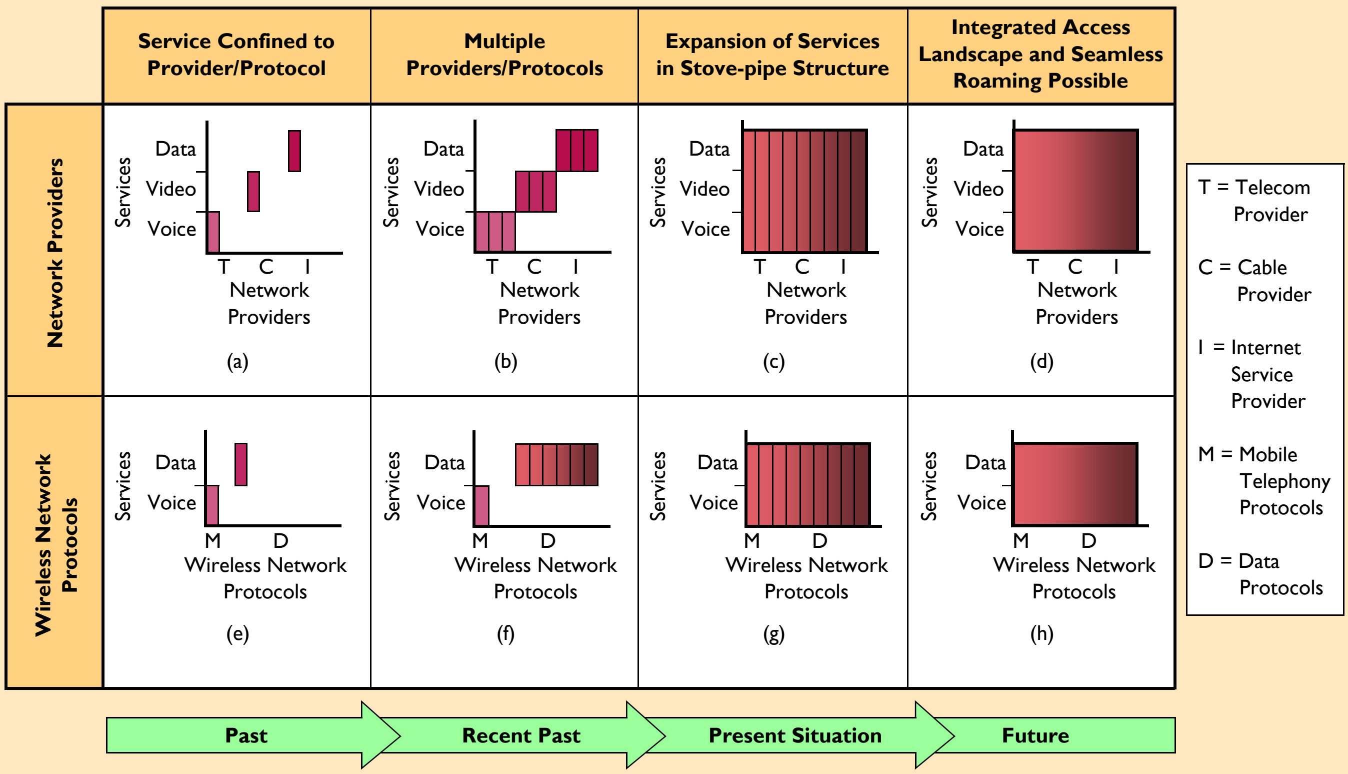
Introduction

During the last decade, GSM technology (and more recently GPRS and UMTS) have made an impressive entry into a world where fixed telephony dominated the telecommunications 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 Wi-Fi, Bluetooth, and in the near future WiMAX, UWB and ZigBee, are not necessarily bound to one provider (although the continuously growing number of hot spots operated by a single provider might suggest otherwise). However, interchanging between these technologies to optimise connection characteristics such as available bandwidth, service, QoS and cost is currently not possible. This inability to interchange between providers and technologies is depicted by the stove-pipes in Figure 1(c) and (g).

The foundations of these stove-pipes 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 1(a). After deregulation of the sector new competitors came to the market (multiple bars), as depicted in Figure 1(b). Being active in the telecommunications sector and looking for more revenue, these providers expanded their businesses to other service areas, as can be seen in Figure 1(c). The introduction of triple play (telephony, television and Internet by a single provider) is an example of this. In this scenario, which uses the current situation in the telecommunications sector, different providers can be selected that provide all kinds of services. However, dynamic switching between these providers is not possible, leading to the stove-pipe structure depicted by the multiple bars. In conclusion, users are statically bound to individual providers and their networks.

Figure 1 **Stove-pipe formation prevents dynamic switching between network providers and wireless network protocols**



Similar stove-pipe formations can be observed on a different level. Technical solutions in mobile devices have also resulted in the formation of stove-pipes (Figure 1(g)). The current commercial solutions do not offer the possibility of switching dynamically between different access technologies. Wireless voice services used to be offered exclusively over the GSM network and wireless data services needed specialised protocols such as Wi-Fi and Bluetooth (Figure 1(e)). The number of wireless technologies and their associated protocols increased at a rapid pace (multiple bars) as shown in Figure 1(f). 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 mobile networks. This led to the present situation shown in Figure 1(g). In this situation many different wireless technologies coexist that provide both data and voice services. Dynamic switching between the different technologies is very difficult, because of the different protocols used by these technologies. This has resulted in a stove-pipe 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 stove-pipe structure in the case 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 1(d) and (h). In this future scenario, the stove-pipe 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 a reality, the selection process should not be left to the end user. Users should not be bothered by 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 reason 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. We elaborate on this system in the remainder of this article.

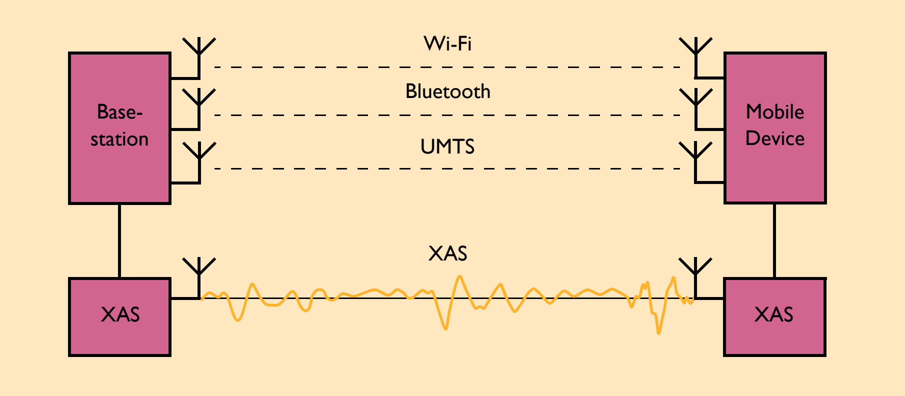
Multiple Wireless Protocol Advertising System

We propose an advertisement system called XAS. This stands for 'X Advertising System', pronounced '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 set-up of XAS is schematically depicted in Figure 2.

Figure 2 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).

automatic selection of the best available technology and provider to establish a data connection would very much benefit the end user

Figure 2 Set-up of the advertisement system XAS



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 stand-by 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. Note that the power consumption of a Wi-Fi 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.

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 is needed which will deplete the battery in a very modest way.

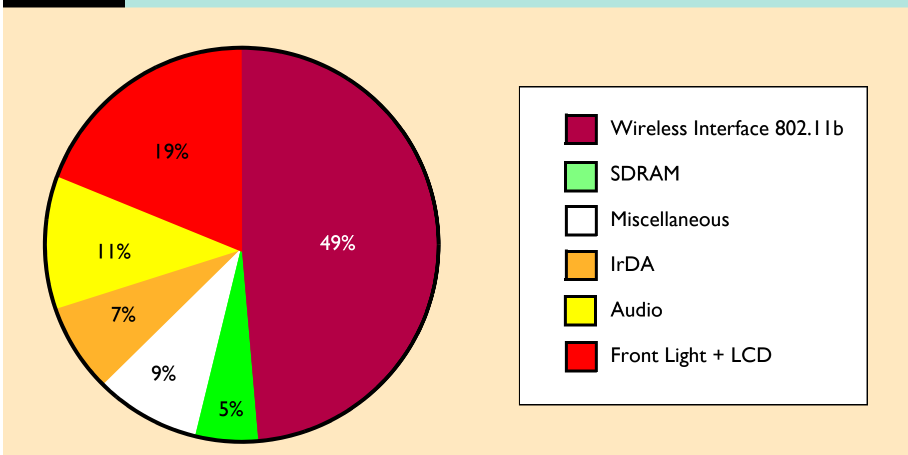
The power consumed by the low-power XAS protocol is substantially lower than any single existing protocol adapter would consume, because only the low power receiver remains active. This way a reduction in power consumption is achieved.

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 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 customised 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.

Figure 3 Power consumption of a Wi-Fi interface in a PDA



There are two types of terminal, base-station and mobile device, and therefore four types of interaction. These four types of interaction are shown in the four quadrants of Figure 4. Every quadrant shows example services that can be enabled. It is important to observe that these services do not necessarily have to be relevant to the telecommunications sector – they are of potential value in other sectors as well.

User-profile-based services enable the futuristic scenario shown in the movie *Minority Report*. In this movie a person walks through a shopping mall and is addressed by his name by billboards. Apparently, these billboards are able to recognise instantly 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 customise the displayed content to the dynamic demographic distribution of people in their direct surroundings.

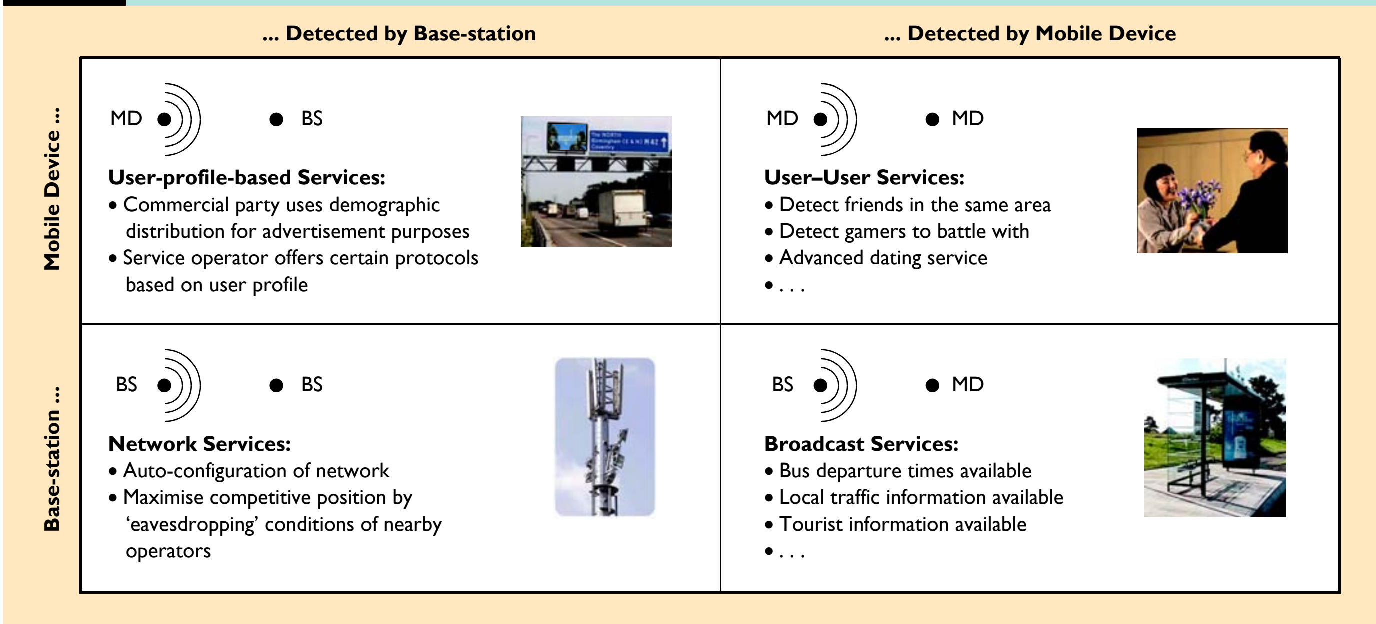
Examples of other services include the following.

- 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 Wi-Fi connection in a train or aircraft.
- Network services
  Multiple Wi-Fi access points within each others' range could advertise their channel utilisation and automatically configure their wireless channels to ensure the least interference.
- 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, they can simply open an accompanying link to establish the Wi-Fi connection that presents this data.

Implementation of the XAS-Demonstrator

It was mentioned earlier that the XAS concept has been built as a pre-commercial

Figure 4 XAS enables four types of detection service



demonstrator. The demonstrator set-up 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 set-up was realised with a transceiver-module mounted on a field programmable gate array (FPGA) development board. The transceiver operated in an unlicensed frequency band at 434 MHz. The data rate was set at 19.2 kbit/s using frequency shift keying (FSK). The medium access control algorithm employed was a form of carrier sense multiple access based on the IEEE802.11 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 screen shot of the demonstrator is shown in Figure 5.

The XAS Demonstrator Shows the Capabilities of and Opportunities for XAS in Four Scenarios

The demonstrator has been built to display the capabilities of and opportunities for XAS in four scenarios:

- it demonstrates the capability of automatic access selection;
- it shows the opportunities for broadcast services;
- it shows the possibility of user–user services;
- 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 newly instigated service based on the profile of that service. Three profiles were defined for the demonstrator:

- data services that would require limited available bandwidth and QoS – an example that fits this profile is an e-mail application;
- voice services that require limited available bandwidth but a high QoS-level;
- customised video services which require the availability of considerable connection resources.

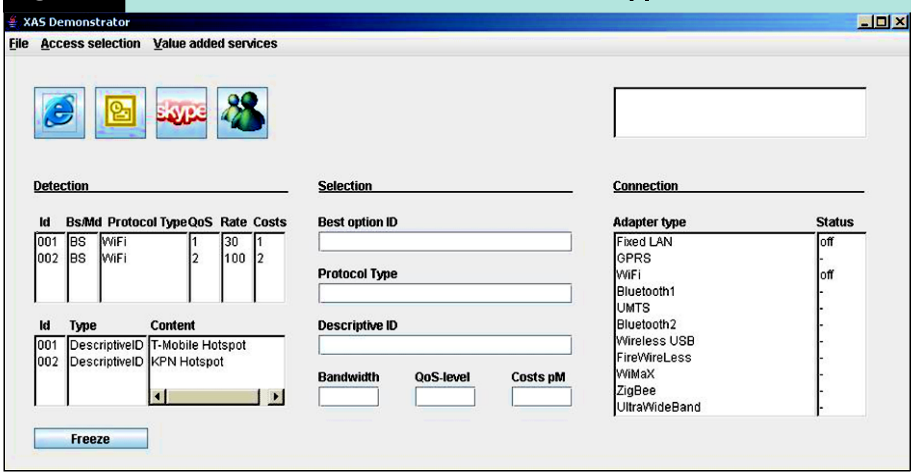
These profiles can be observed in Figure 6. When a service was started, the demonstrator showed the selection of the access option with the lowest cost that satisfied the requirements of the requested service.

The second scenario shows the ability to provide broadcast services. A base-station can advertise the availability of certain local information in its broadcast XAS messages. If the user is interested, they 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 can designate other devices as 'friends'. When two friendly mobile devices move within each other's 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 of the demographic distribution of people can be obtained by collecting the broadcast profiles of the owners of mobile devices in the vicinity of the base-station. Random variations in this distribution can be used to customise commercial

Figure 5 Screen shot of the XAS demonstrator application



advertisements and billboards, so that the displayed advertisements 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. These examples merely show a few possibilities of interesting services that are based on the location of the user.

XAS Reduces the Negative Effect of Idle Adapters on the Stand-by 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. The achievable gain in stand-by 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;
- the power consumption of XAS.

This exercise has considered a scenario with a PDA with one network interface (Wi-Fi). For the power consumption of the PDA an average stand-by 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 Wi-Fi 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 figures used to calculate the achievable power gain can be seen 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 stand-by times of the PDA with and without use of XAS. It can be observed from this chart that configurations with one or more Wi-Fi cards diminish the stand-by time of the device. The configuration with XAS, however, reduces this negative influence of idle adapters on the stand-by time of the mobile device.

Conclusions

In the present situation, the variety in protocols and corresponding connectivity options has given rise to three challenges:

Figure 6 Example service requirement profiles

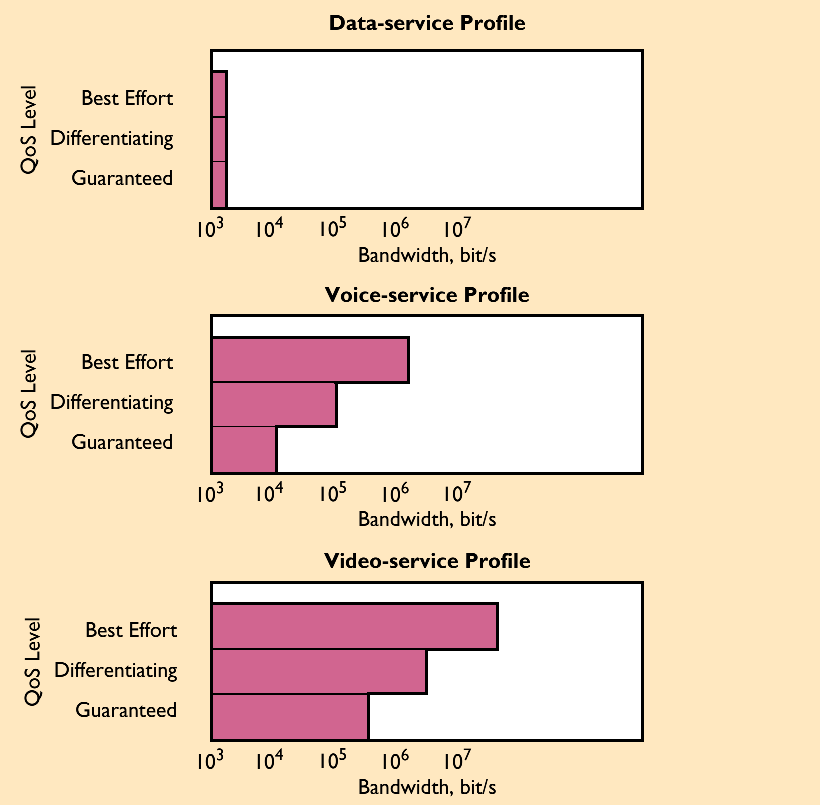
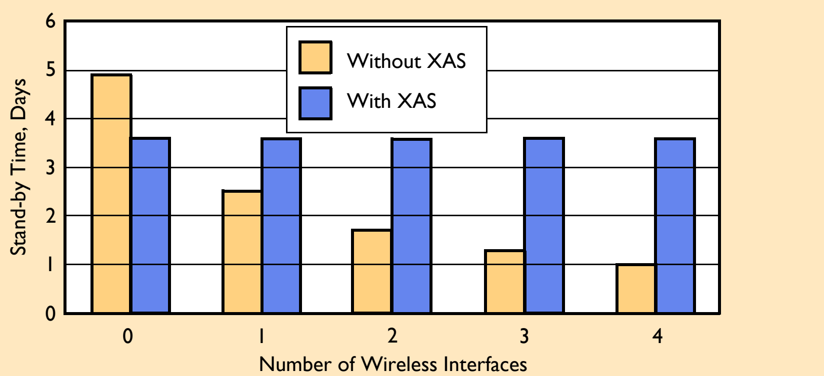


Table 1 Power Consumption Characteristics

Device/component	Type	Active current†	Idle current†
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	Wi-Fi card	161 mA	12 mA
Cisco AIR-PCM350	Wi-Fi card	216 mA	9 mA
RX5000	Receiver	3.8 mA	–
TX5000	Transmitter	7.5 mA	–

† Active/idle power consumption of PDAs determined by dividing battery capacity by active/stand-by times as indicated by vendor. Power consumption characteristics of Wi-Fi cards obtained from Agarwal and Rajesh [2]. Power consumption of transmitter/receiver obtained from Shih et al [3].

Figure 7 Stand-by time of an average PDA without and with XAS, assuming 15 min of voice services per day and 15 min of wireless data services per day



- to enable automatic access selection;
- to reduce the negative influences of idle adapters on the stand-by time of mobile devices;
- 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 article has outlined 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 which has displayed the technical feasibility and the functionality of XAS.

The concept of automatic access selection can now be shown and it can also be proved that XAS indeed results in the selection of the best available option, yielding major benefits for the user. Theoretical exercises have shown 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.

Biographies

Skief Houben
Delft University

Skief Houben holds an MSc in Electrical Engineering with a specialisation in Telecommunications from Delft University of Technology in the Netherlands (2006). He conducted his thesis research on the development of a Multiple Wireless Protocol Advertising System.

skief@houben.cc

Nico Baken
Delft University

Professor Nico 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 fibre 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 advise the Dutch government on the matter of broadband and the roll out of fibre to the home (FTTH) in the national broadband expert group and in the Andriessen committee (former minister of Economic Affairs) to deal with the FTTH for Amsterdam and the Hague. He finished Gymnasium β 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 has won several prizes for his scientific work, for example, the Dr Neher Laboratory prize (yearly prize for the most outstanding researcher). He received his PhD from the department of Electrical Engineering at the Technical University of Delft, working with Professor H Blok and Professor A T de Hoop.

N.H.G.Baken@ewi.tudelft.nl

Philippe Hervé
Alcatel-Lucent
Technologies

Philippe Hervé is part of the Alcatel-Lucent CTO organization in charge of, among others, enterprise and vertical segments in Europe and North. Prior to his new function, he was directing a research team in Bell Laboratories on access technologies. Dr Herve has been involved in innovations and technologies for telecommunications for the last 15 years. His main interest is the application of broadband services and technologies in new market segments, such as transportation, government, and health. He holds a PhD from Eindhoven University of Technologies and an MSc from Montpellier University.

hervep@alcatel-lucent.com

Rob Smets
Alcatel-Lucent
Technologies

Rob C J Smets received his PhD degree on High Speed Optical Communication and Signal Processing from the Eindhoven University of Technology in September 1999. In May 1999 he joined Lucent Technologies' Bell Labs, where he is a researcher in various telecommunications fields, ranging from core networks to access networks. He covers topics ranging from the application layer to the physical layer. Currently he provides technical support and consultancy for the Access Network Division of Alcatel-Lucent.

smets@alcatel-lucent.com

References

1 Baken, N. H. G., Boven, E. Van, Hartog, F. den and 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. and 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, and the Department of Computer Science and Engineering, University of California at San Diego, 2003.

3 Shih, E., Bahl, P. and 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 – http://www.rfm.com/