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Mapping standards for home networking

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ABSTRACT

In this study, we apply a step-by-step approach for the identification of standards for home networking. We develop a classification and we use this classification to categorize sixty-four (sets of) standards. By developing this categorization, we have brought order to the chaos of home networking standards.

1. Introduction

The situation where different types of technology in a home environment can communicate with each other and form one home network is becoming a viable one. Irrespective of the fact that the home network has been technically possible for many years and that there seems to be a demand for it [1], it has not yet become a practical reality. The lack of a dominant standard for the interconnection between subsystems of the home network is one of the primary reasons why the home network has not yet emerged [1–3]. One of the explanations behind the fact that not one dominant standard has, as of yet, emerged is the mere amount of standards that exist in the market for home networking. We intend to reach order by applying a step-by-step approach to the identification of standards and we try to classify the standards.

We start by studying the system in which the standards are used with the aim of developing our categorization. Next, we will give an overview of the different standard setting organizations that are involved. Subsequently, for each standard setting organization, we will provide the standards and we will classify them according to the categorization developed.

In 2002, Den Hartog et al. [4] performed a similar study. Our study builds on, and extends, the study of Den Hartog et al. [4] in several ways. First, we will take into account standards that were developed from 2002 to 2007. Second, by applying a step-by-step approach, we intend to reach a more complete list of standards. Third, we will develop a classification which can be used in future study to better compare the different standards to each other.

2. Analysis of the home network

2.1. Architecture of the system

The home network should be seen in a larger context in order to fully understand it. In Fig. 1, an architectural overview of an end-to-end communication network is presented. The core network enables the communication of information between service providers, whereas the access network enables the communication of information between the service provider and the consumer. Our interest lies in the private network, which enables the communication of information in the home. Attached to this network is the home platform in which several subsystems (such as consumer electronic devices) are located which can, by making use of the private network, communicate with each other. Through the home interface, which consists of the residential gateway, the subsystems used in the home platform can communicate with the outside world. In the access platform, access to the internet and billing services are located and the service platform is both a multimedia and an open services platform.

2.2. Type of standards related to the architecture of the system

In this study, we will primarily focus on compatibility standards since they are crucial for the connection of subsystems in a larger system [5]. We will define a compatibility standard as a codified specification defining the interrelations between entities [6] in order to enable them to function together [5]. In our search, we will take into account both proprietary and open standards, but also understand that the existence of proprietary standards will not always be

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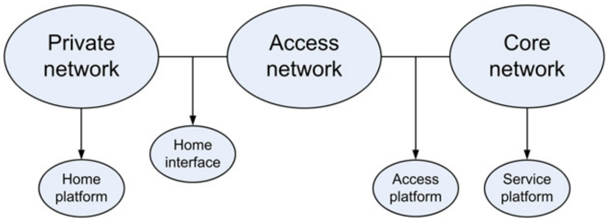

Fig. 1. Architectural overview of the home system [11].

communicated, decreasing the number of proprietary standards that we find.

Standards are defined at different layers in the architecture of a system [7]. Since home networking standards in practice provide partial or complete solutions for *application*, *communication* or *network* concepts, we will distinguish between application service standards, communication service standards and network service standards. Application service standards originate from the need to resolve the functional, communication and network requirements of one or more applications with independent distributed functions. These concepts specify a generic application model and application messaging process, the process for message communication and the solution(s) for networking that support the application, messaging and communication requirements. Often, these standards are referred to as "middleware." Communication service standards originate from the need to resolve the communication and network requirements in an application environment with unnamed distributed functions. These concepts specify a generic communication model and process to transport data between application processes and the solution(s) for networking that supports the communication requirements. Network service standards originate from the need to resolve the network requirements for the communication support for distributed functions, proposing a typical medium-dependent solution for the transport of certain volumes of data between several (independent) nodes [8].

We make a distinction between the subsystem and system levels, since we focus on systems that (at least partly) consist of established subsystems. The established subsystems, located in the home platform in Fig. 1, usually already apply standards which can *potentially* also be used for the connection between these subsystems. We call these *subsystem standards*. Examples include GSM and Coax. We will call the standards that are newly developed for the interconnection of the established subsystems *system standards*. These standards concern the private network. Examples include Konnex and Zigbee. A third category of standards are subsystem standards that were originally used for the interconnection in one subsystem but are now also used to connect these subsystems to other subsystems. We will call these standards *evolved subsystem standards*. Examples include USB and Wifi. In Fig. 2, this is graphically illustrated. In system X, subsystem standard 1 has evolved into a system standard and now connects established subsystems A and B. Subsystem standard 2 could potentially also be used for the interconnection of established subsystems A and B. In system Y, a system standard connects the subsystems. To determine whether a standard can be categorized as being a subsystem or a system standard, we will look at the original purpose of the standard. When the standard was originally developed for home networking, it is categorized as a system standard. When it was originally developed for one particular subsystem within the home network it will be categorized as a subsystem standard.

3. Converging worlds

The home network market consists of different product markets that are converging with each other. Each product market consists of its own technologies, subsystems, and standards. Standards that originate from one product market may potentially be used to realize communication in the complex system and must therefore also be taken into account in this analysis. This increases the total amount of standards even more. We will distinguish four basic product markets: information technology (including hardware and software), consumer electronics, telecommunications, and home automation [9,10].

The information technology product market is characterized by products that have a PC architecture and a generic (Intel, AMD, etc.) processor. There is a fair amount of standardization of communication protocols and accessories (storage, printers, etc.) but little standardization of operating systems and applications (since the market is arguably an oligopoly dominated by Microsoft with Apple and Linux

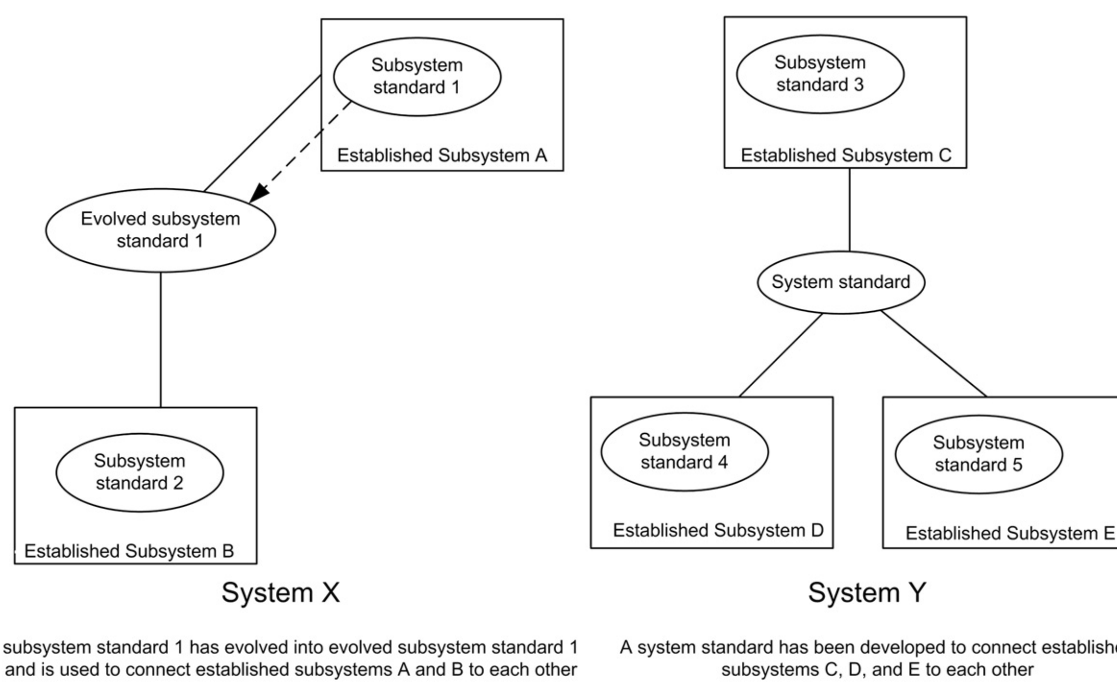

Fig. 2. System, subsystem, and evolved subsystem standards.

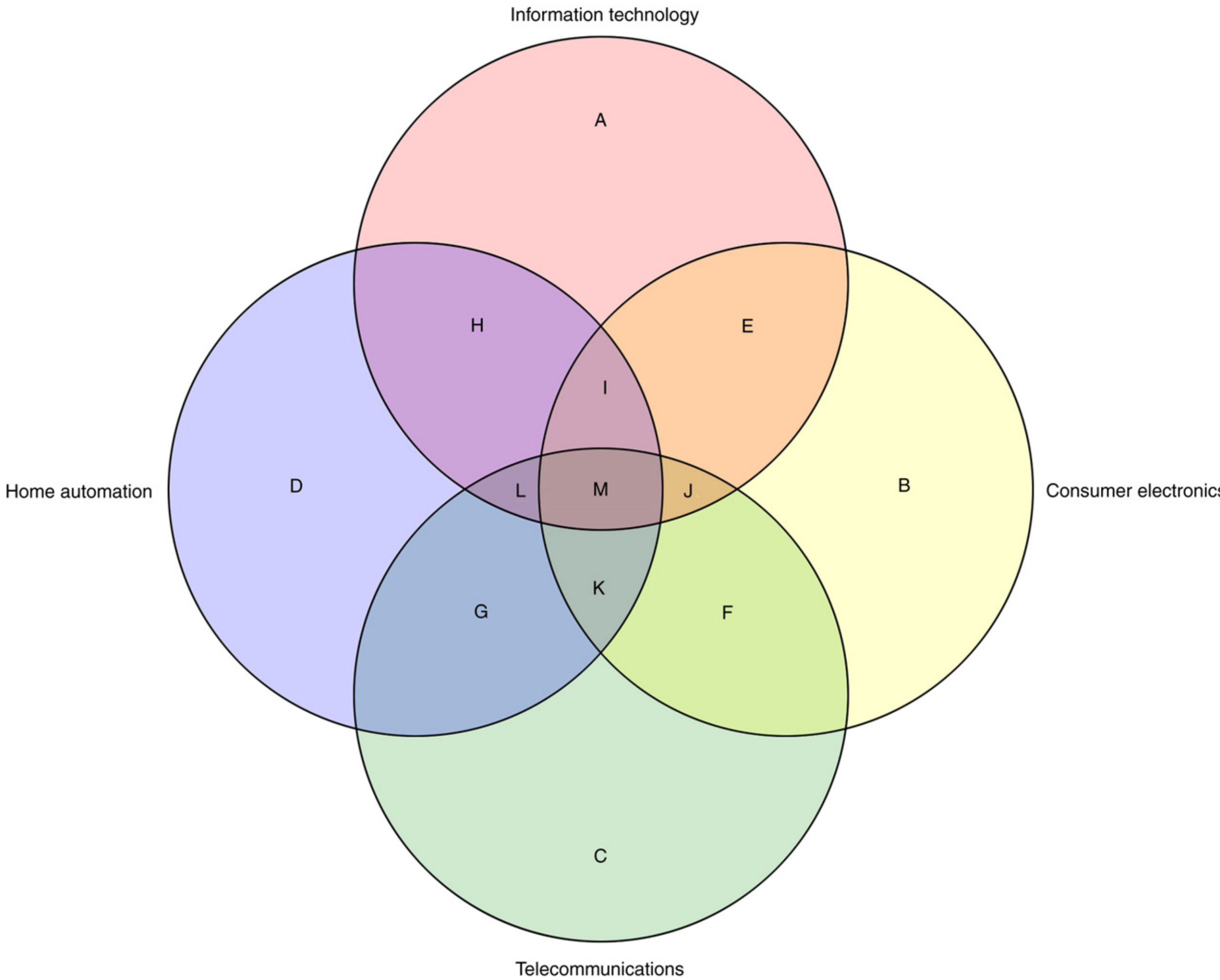

Fig. 3. The different product markets in home networking.

as small players). The average product life cycle is 3 years, prices and margins are quite high.

The consumer electronics product market is characterized by products having a more specific architecture and processors (Philips, TI, NSC, etc.). Furthermore, there is little standardization of communication protocols but a fair amount of standardization of formats (CD, DVD, MP3, MPEG2, etc.). The consumer electronics product market has an average product life cycle of 5 to 10 years (with the exception of the gaming console market); it is an open market with a high number of suppliers and low prices and margins.

The telecommunications product market is characterized by products having a specific architecture and processors that are delivered by an operator (where the consumer electronics product market and the computer product market are more retail based). There is a fair amount of standardization of communication protocols and subsidized business models (margins are from subscriptions instead of retail prices). The average product life cycle is lower then 3 years and there exists a small open market (with few operators, of which one is dominating) and a couple of suppliers (such as Lucent, Alcatel, Ericsson, and Nokia)

The home automation product market is characterized by products with very low prices and margins, an open market with a lot of players (such as Honeywell, Schneider, etc), and little standardization of communication protocols. Product life cycles are longer than 10 years.

These markets are converging with each other which results in a total of fifteen different categories of standards. We will call these standard types A, B, C, etc., so a Type A standard is a standard which originates from the information technology product market and a type K standard originates from a convergence of the consumer electronics, home automation and telecommunications product markets, see Fig. 3.

Table 1
Formal standard setting organizations.

Formal standard setting organization	Further information
European Committee for Electrotechnical Standardization (Cenelec)	http://www.cenelec.org/
European Committee for Standardization (CEN)	http://www.cen.eu/
European Telecommunication Standards Institute	http://www.etsi.org/
International Electrotechnical Commission (IEC)	http://www.iec.ch/
International Organization for Standardization (ISO)	http://www.iso.org/
International Telecommunications Union (ITU)	http://www.itu.int/

4. Classification of standards

Trade associations and industrial consortia are developing and promoting their own standards. We will concentrate on the different product categories from Fig. 3 to reach a complete overview of all the standard setting organizations involved. To identify these organizations, we have searched the internet using the terms “trade association,” “home network,” “home system,” “alliance,” etc. Furthermore, we have discussed our list of organizations with several experts to ensure that the most important standard setting organizations were included. The resulting list of standard setting organizations is presented in Tables 1 and 2.

Table 2
Other standard setting organizations.

Standard setting organization	Further information
10 Gigabit Ethernet Alliance	http://www.10gea.org/
1394 Trade Association	http://www.1394ta.org/
American Society of Heating, Refrigerating and Air-Conditioning Engineers	http://www.ashra.org/
ARCNET Trade Association	http://www.arcnet.com/
Association of Home Appliance Manufacturers	http://www.aham.org/
ATM Forum	http://www.atmforum.com
BatiBUS Club International	http://www.batibus.com
Bluetooth Special Interest Group (SIG)	http://www.bluetooth.com/Bluetooth/SIG/
Broadband services forum	http://www.broadbandservicesforum.org/
Cable Television Laboratories, Inc. (CableLabs)	http://www.cablelabs.com/
CE Powerline Communication Alliance	http://www.cepca.org
CEBus Industry Council (CIC)	http://www.cebus.org/
COBA Project	http://www.consortiuminfo.org/
Consumer Electronics Association	http://www.ce.org/
DECT forum	http://www.dect.org/
Digital Display Working Group	http://www.ddwg.org/
Digital Living Network Alliance	http://www.dlna.org/
DSL forum	http://www.dslforum.org/
Easyplug	http://www.easyplug.com
Echonet Consortium	http://www.consortiuminfo.org/
ECMA International	http://www.ecma-international.org/
Electronics Industry Association of Japan (EIAJ)	http://www.jeita.or.jp/eiaj/english/
EHS Association	http://www.ehsa.com/
EIB Association	http://www.eiba.com/
Electronic Industries Alliance	http://www.eia.org/
Enhanced Wireless Consortium	http://www.enhancedwirelessconsortium.org/
Ethernet User Alliance	http://www.consortiuminfo.org/
European Home Systems Association	http://www.consortiuminfo.org/
Extent The Internet Alliance	http://www.consortiuminfo.org/
Fiber To The Home Council	http://www.ftthcouncil.org/
Frame Relay Forum	http://www.frforum.com/
HAVi Consortium	http://www.havi.org/
High-Definition Audio–Video Network Alliance	http://www.hanaalliance.org
HiperLAN2 Global Forum	http://www.consortiuminfo.org/
Home automation association	http://www.homeautomation.org/
HomeAPI WorkGroup	http://www.consortiuminfo.org/
Home Cable Network Alliance	http://www.consortiuminfo.org/
Home Gateway Initiatve (HGI)	http://www.consortiuminfo.org/
Home Phoneline Networking Alliance (HomePNA)	http://www.homepna.org/
Home Plug and Play task force	
HomePlug Powerline Alliance	http://www.homeplug.org/
HomeRF workgroup	http://www.consortiuminfo.org/
Infra-red Data Association	http://www.irda.org/
Institute of Electrical and Electronics Engineers (IEEE)	http://www.ieee.org/
Internet Engineering Taskforce	http://www.ietf.org/
IPV6 forum	http://www.ipv6forum.com/
Konnex Association	http://www.konnex.org/
Lonmark Interoperability Association	http://www.consortiuminfo.org/
MFA/IPMPLS forum	
MPLS and Frame Relay Alliance	http://www.mplsforum.org/
Multiband OFDM Alliance (MBOA)	http://www.multibandofdm.org/
Multimedia over Coax Alliance	
Multi Protocol Label Switching Forum	http://www.mplsforum.org/
OFDM-forum	http://www.ofdm-forum.com
OPC Foundation	http://www.opcfoundation.org/
Object Management Group	http://www.omg.org/
Open PLC European Research Alliance	
OSGi Alliance	http://www.osgi.org/
PLC Forum	http://www.plcforum.org
Power Line Communications Association	http://www.plca.net
Salutation Consortium	http://www.consortiuminfo.org/
Security Industry Association	http://www.siaonline.org/
Telecommunications Industry Association	http://www.tiaonline.org
Wireless LAN Trade Association	http://www.wlana.org/
Universal Home API	http://www.uhapi.org/
Universal Plug And Play Forum	http://www.upnp.org/
Universal Powerline Association	http://www.upaplc.org/
USB Implementers Forum (USB-IF)	http://www.usb.org/about/
UWB Forum	http://www.uwbforum.org/
Video Electronics Standards Association (VESA)	http://www.vesa.org/
WIFI Alliance	http://www.wi-fi.org/
WIMAX forum	http://www.wimaxforum.org/
WiMedia Alliance	http://www.wimedia.org/
Wireless Ethernet Compatibility Alliance (WECA)	http://www.consortiuminfo.org/
Wireless LAN Interoperability Forum	http://www.wlif.org/
Wireless USB Promoter Group	
World Wide Web Consortium (W3C)	http://www.w3.org
ZigBee Alliance	http://www.zigbee.org/

To reach a complete list of standards, we have analyzed standards that have been developed and/or are being promoted by the standards organizations mentioned in Table 2. In this analysis, we take into account all four product markets mentioned in Fig. 3. It might be that standards for home networking have not been developed in one of the four product markets which we analyze. To overcome this problem, we have searched the complete list of standards developed by each standard setting organization for the terms "home network," "home system," etc. We then filtered out all standards that are not compatibility standards. An expert in the area of home networking standards chose the most important formal home networking standards (developed by the standards organizations mentioned in Table 1) to be included in the study. This resulted in a list of sixty-four sets of standards that might be used for home networking. Each set consists of one or more standards. In the latter case, the set defines a complete architecture specified in different standards. This list can still be further filtered with respect to the relevance of each standard as a home networking standard. Not all standards are equally relevant. The completeness of the list also depends on whether the standards are publically available on the websites analyzed.

We have categorized the sixty-four sets of standards using the classification developed in sections 2 and 3 by interviewing several experts in the field of home networking. The results are presented in Table 3. For thirteen categories, more than one standard exists.

5. Conclusion

In this study, we have applied a step-by-step approach for the identification of standards for home networking. Furthermore, we have developed a classification and we have used this classification to categorize sixty-four (sets of) standards (see Table 3). In Fig. 4, we summarize the standards according to the product market for which they apply. Type N standards define communication for products in both the information technology and telecommunications product markets (such as IP telephony) and type O standards define communication for products in both the home automation and consumer electronics product markets.

It can be concluded that the convergence of home networking standards is only apparent among the product categories of information technology, consumer electronics and telecommunications. Home automation still lags behind. Perhaps the reason for this could lie in the fact that companies active in home automation are mostly small and lack the financial resources for inter industry collaborations. Furthermore, convergence has not resulted in class M standards yet. A possible explanation for this could lie in the possibility that the actors that promote the standards are primarily interested in keeping their market position in the product market from which they originate. Their secondary objective is to reach dominance in the converging areas of Fig. 4. Therefore, we surmise that they generally prefer to cooperate with actors within the product market from which they

Table 3
Classification of standards for home networking.

	Application supporting			Communication service			Network infrastructure		
	Subsystem standards	Evolved subsystem standards	System standards	Subsystem standards	Evolved subsystem standards	System standards	Subsystem standards	Evolved subsystem standards	System standards
A			EMIT				TCP/IP IPv4 XML HTTP Token Ring Token Bus XTP	Ethernet USB Passport WIFI	IPv6 Smart House JINI
B						AHAM	HAVi COAX	SCART	
C							GSM GPRS UMTS SSERQ	DECT ISDN Norm88	EIA 570-A
D			KONNEX EHS HES COBA			LonTalk BatiBUS EIB BACnet			X10 Metasys DALI Echonet Spanningsnet
E			UPnP					FireWire HomeCNA	VESA
F									
G									
H			Salutation				IrDA		Zigbee
I						HBS			
J								UWB Fiber Homegateway	Homeplug Powerpacket CableHome
K									
L	HomeGate		OSGi						
M									
N			HiperLAN2					Bluetooth	ATM HomeRF HomePNA IEEE 802.15.3 Corba
O									CEBUS

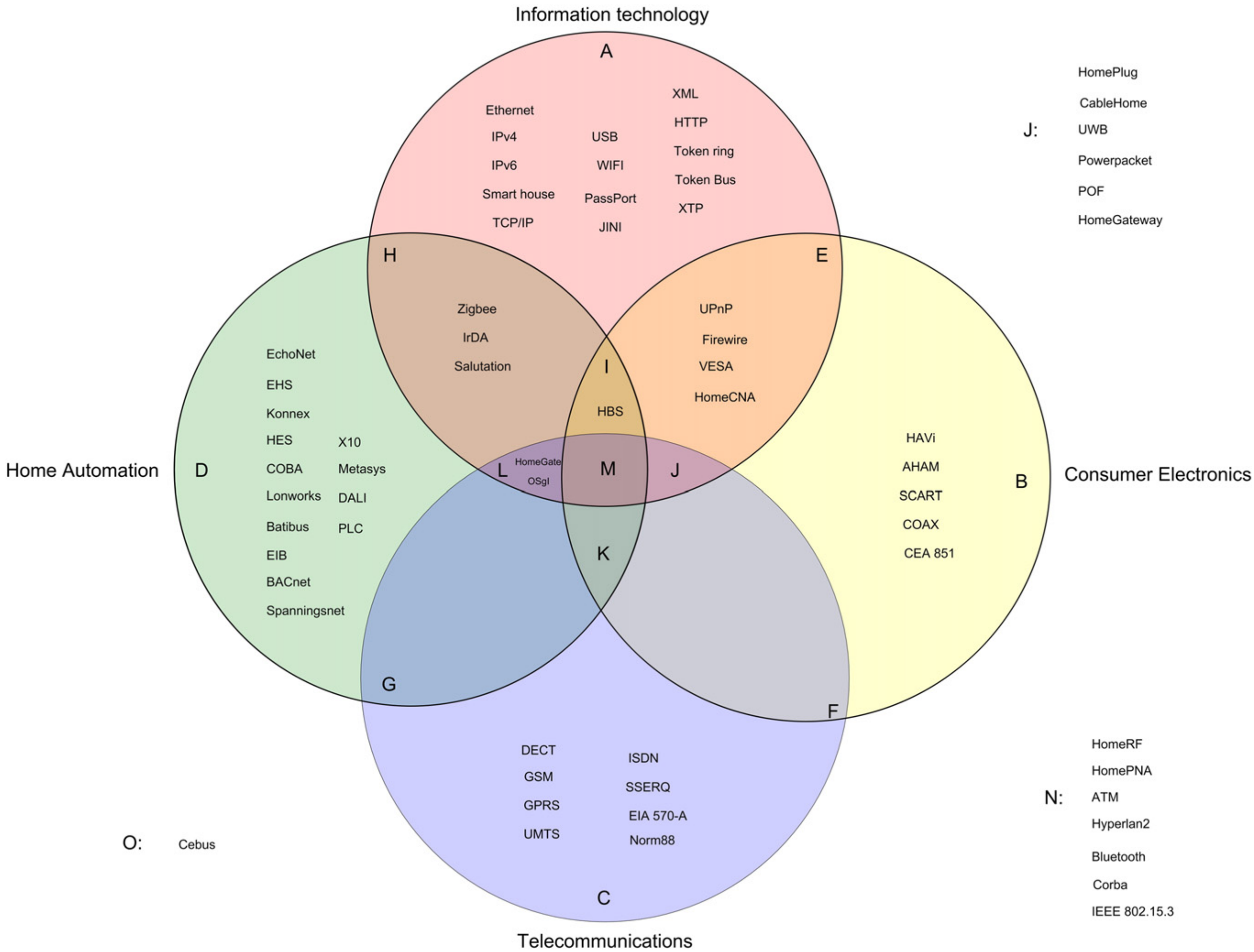

Fig. 4. Standards originating from different converging product markets.

originate than with actors from product markets with which they converge. Furthermore, *if* actors do cooperate across product markets, the primary reason for this cooperation is to keep competitors away from their product market, rather than to work together to try to establish a class M standard. Although this strategy is acceptable in the short run, it is questionable whether it is of value in the long run given that product markets continue to converge over time. A clear recommendation to actors in the home networking industry would be to cooperate across product markets. A recommendation for further research would be to investigate the effects of cooperation across product markets on the chances that home networking standards reach dominance.

We conclude that by developing a categorization and using it to classify home networking standards we have brought at least a certain amount of order to chaos. However, some problems still remain. For instance, we have found a total of 6568 formal standards. Furthermore, we know that many more standards exist, but it is more difficult to trace these because they have no common 'address' and in some cases they are not publicly available. This opacity adds to the complexity of the situation and makes it difficult for manufacturers to decide which standards to implement in their products.

Also, in Table 3 we presented sixty-four (sets of) standards and we came to the conclusion that not one of them has become dominant yet. This not only illustrates the problem in home networking, but also says something about the remaining formal standards that have not been taken into account. We assume that in these standards the same problems occur.

Some of the 64 (sets of) standards have turned out to be unsuccessful in the market, whereas others have achieved market acceptance, at least to a certain extent. However, none of the standards have become dominant home networking standards illustrating the problem in home networking. It would be interesting to study which factors affect the chances that standards will become dominant in the home networking industry. This could be an interesting topic for further research.

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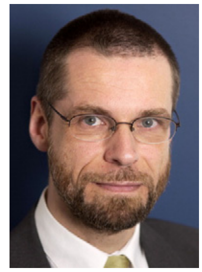
Frank den Hartog is a senior scientist Heterogeneous Consumer Networking, working for the TNO since 2003. In 1998 he received a Ph.D. from the Leiden University on laser spectroscopy of glassy materials. He then went to KPN Research, where he founded and lead the Consumer Networks group. He was the project manager of the Dutch collaborative research project "Residential Gateway Environment" and "Freeband Personal Network Pilot 2008". He is co-chair of the technical working group of the worldwide industrial standardization consortium Home Gateway Initiative. He is internationally known as an architect of the heterogeneous home networks, Residential Gateways and Personal Networks, on the data layer, control layer, as well as the management layer. He wrote about 70 international technical journal papers, conference papers, patents, book chapters, and standardization contributions. He is a member of the IEEE.



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