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Internet – Intranet – Infranet: A Modular Integrating Architecture

Tom Pfeifer
GMD FOKUS
Kaiserin-Augusta-Allee 31, D-10589 Berlin, Germany
pfeifer@fokus.gmd.de

Abstract

Based on an analysis of the heterogeneous systems for interconnecting distributed infrastructural devices, such as low-bandwidth sensor/actuator-networks and upcoming multimedia home networks, the paper proposes an integrating architecture for accessing various infranets via intranets and the Internet as well as telecommunication networks. Its modularity allows the rapid creation of new application scenarios. Keywords: Web-based computing, Java-based network programming, Infranet, Intranet, Applications of Distributed Systems

1. Introduction

The revolutionary progress in the convergence of computing and telecommunication technologies is set to globally transform the fundamentals of commerce, politics, and culture – redefining the way we all live, work, learn, and play. New application scenarios are enabled within shorter and shorter periods of time.

Today's communication as known from public switched telephone networks (PSTN) and the Internet, is global – but in a very limited sense. These networks can be reached from almost anywhere in the world, but the end-systems are an estimate of 60 million computers connected to the Internet, and nearly 800 million telephones.

Beside these "traditional" communication end-systems, there are already more than 12 billion sub-computer devices equipped with micro controllers [25]. These devices are used in nearly every area of actual life, ranging from car engine control, heating systems, video cassette recorders, alarm and surveillance systems, elevator control, room access restriction, light scene settings, household appliances, up to the whole area of industrial automation.

These devices collect and process an enormous amount of information. However, as they are not connected to networks at all or only to networks dedicated to the specific application environment (e.g. an automation process), they are not able to share the gathered information or their processing results.

Such automation networks are quite heterogeneous, often very proprietary, partly traditional, partly innovative. They range from serial lines and buses (RS232, RS422), industrial control networks (Fieldbus, AnyBus), building automation networks (LON, EIB, InstaBus), to newer sub-computer wired and wire-less links and networks (USB, FireWire, Bluetooth, IrDA). Few approaches try to bridge or harmonize such networks, and usually only within the same category. Section 2 provides an analysis of the features of each of these systems.

Each sub-computer system works nicely at its own, however, their interaction would enable an impressing number of new applications. The current relevance is driven by the existence of thousands of such networks already installed, connecting millions of legacy devices. Most existing consumer electronics devices do not provide appropriate interfaces for innovative applications. Finally, we cannot wait until every refrigerator has its IPv6 number.

In{ter|tra|fra}net, the tongue twisters distinguished by one or two letters respectively, should here be understood as follows (cf. Figure 1, based on [25]):

- the Internet – the full-size-computer interconnection with worldwide access,
- an intranet, the same type of interconnection, but with restricted access,
- an infranet – a sub-computer network controlling infrastructure.

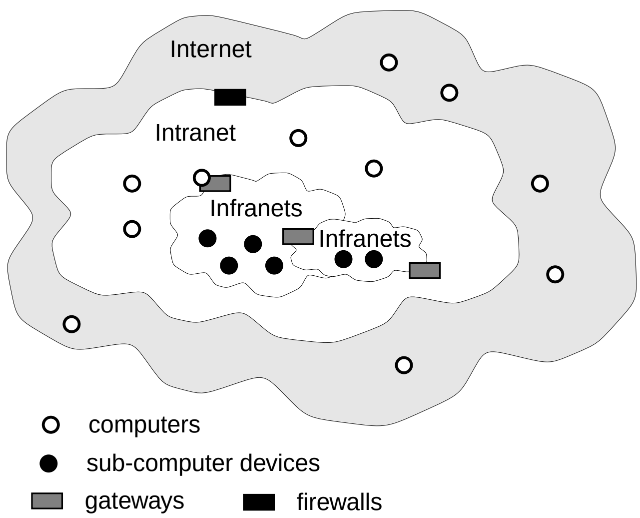

Figure 1 Internet – Intranet – Infranet hierarchy

Within this context, GMD FOKUS and an industrial partner have established the creation of a modular platform, focusing on the integration of infranet technology, already installed or newly planned, into Internet and intranet scenarios.

The project is based on sound experience within the institute regarding system integration, location aware technology, Personal Communication Support (PCS), filtering and dynamic conversion of communication media, middleware platforms, and mobile agents.

The resulting platform supports a wide range of applications with support for information, navigation, localisation, facility control/management and communication in different scenarios. In addition, the platform is designed to integrate services from third party vendors in these areas.

This paper discusses the related work next, followed by the description of the proposed architecture in section 3 and application examples in section 4.

2. Related Work

The discussion of related work focuses on current tendencies as well as examples for the heterogeneity of the current situation, not necessarily on completeness.

2.1. Automation and building networks

The Local Operation Network (LON) [10] developed by EcheLON, supports free topology twisted pair cabling for 78 Kbit/s, backbone structures for 1.25 Mbit/s or power line networks. It introduced the Neuron chip with three pipelined micro controllers, running a proprietary communication protocol and some application software. The LonWorks Network Services provide a multi-client / multi-server-platform for installation and maintenance.

The European Installation Bus (EIB) [11] is a system for home and building automation in free topology with a bitrate of 2.4 Kbit/s. EIB is supported by more than 100 companies in 15 countries. InstaBus is the brand name from Siemens, BatiBus is the French version of EIB.

The European Home System (EHS), developed by European manufacturers, provides a low-cost plug-and-play network (various low voltage cables, power line, IR, radio) with an open, layered technology and object-oriented command language. There are alliances towards EIB and other systems.

HomeRun, developed by the Home Phoneline Networking Alliance [21] of computer manufacturers and telecoms, aims to re-use existing telephony wiring within households by sharing the frequency band between POTS (20 Hz...4 kHz), xDSL (25 kHz...1.1 MHz) and a simple high-speed Ethernet (above 2 MHz) for data rates of 1...10 Mbit/s.

The Controller Area Network (CAN) has been developed mainly for usage in cars, but is used today for many automation purposes [12]. Its CSMA/CA (Collision Arbitration) serial bus with multi-master and real-time capabilities allows inherent prioritizing (e.g. functional commands for brakes, motor control have priority to supportive, like window operation). From 0 to 8 bytes payload can be transmitted with up to 1 Mbit/s in networks up to 40 meters. Decreasing the bit rate allows 1000 meters with 50 Kbit/s.

Further systems for building and industrial automation are CEBus [13], X-10, Fieldbus, AnyBus, etc.; as well as traditional serial lines and buses (RS232, RS422).

Power line transmission approaches are part of most of these systems described above, enabling access to devices in already existing buildings that cannot be reached with low-voltage bus lines. This advantage of using the mains distribution wires is paid for with higher cost of the controllers and additional measures in the electrical installation for line couplers and surge protection. While it is planned to support up to several Mbit/s (facing severe EMC problems), the available products usually support low bit rates up to 4.8 Kbit/s only. Additionally, these approaches have to be coordinated individually with similar activities, such as power plant control signals or Internet access to the curb.

2.2. Sub-computer wired links

The Universal Serial Bus (USB) provides the host-centric interconnection of up to 127 devices within 5 meters and a medium bandwidth of 12 Mbit/s. It is well established in personal computers since a few years now and might coexist with IEEE1394 as the low cost / low bandwidth solution.

IEEE1394-1995 [1] (FireWire) provides a high performance serial bus for 63 devices within 4.5 meters and 98...786 Mbit/s and is supported by about 200 manufacturers. It is hot-pluggable and designed to interconnect high-end audio, video and computer equipment. In contrast to USB, it works without a central host.

A long distance version IEEE1394b [2] (100 Mbit/s over 100 meters) is under development [22] and may support the IEEE1394-1995 bus via repeaters as a backbone. FireWire is the respective initiative by Apple Computers, i.Link the trademark of Sony.

2.3. Wireless links

Wireless technologies are going to cover various complementing areas, namely global/regional, building-wide, and personal/room-wide structures.

Bluetooth [3], supported by many key players in industry, proposes to provide a Wireless Personal Area Network [4] within a working space 10 meters ("pico-network") around the user, focusing on low power (100 mW), small size and low cost (one chip), for a bandwidth of 1Mbit/s. Its design supports isochronous voice and asynchronous data. Identification of the piconet is provided by an specific frequency hopping sequence (up to 1600 hops/s) within the unlicensed ISM band at 2.4 GHz.

The Digital Enhanced Cordless Telecommunication (DECT) [16] provides 1...2 Mbit/s within channels of 32 Kbit/s. It allows low cost end-systems, an operating range of 300 m with average power of 10 mW, supporting a high user density of 500 channels/MHz/km^2.

Wireless LANs (W-LAN) have been developed as a substitute or extension of legacy LANs. More than 100 proprietary products and a few IEEE 802.11 [5] compliant products provide around 2 Mbit/s in the 915 MHz, 2.4 GHz and 5.8 GHz bands. Upcoming improvements (IEEE 802.11a and 802.11b) will achieve up to 11 Mbit/s with 100 mW in an area of 100 meters [6].

The High Performance Radio LAN (HIPERLAN) [7] provides a 20 Mbit/s wireless LAN for indoor usage (50 m) within the 5.15...5.30 GHz band. The HIPERLINK provides point-to-point interconnections of 155 Mbit/s (17 GHz)

The Infrared Data Association (IrDA) [15] of more than 160 companies provides a bandwidth of 115 Kbit/s...16 Mbit/s. Operating within the 850 nm infrared band, its advantages are not to interfere with other electronics and the line-of-sight limitation of the room-confined transmission.

In the context of ongoing activities to provide the user with mobile broadband networking facilities, Universal Mobile Telecommunication Systems (UMTS) [8] will provide a generic core network comprising various radio access networks, either already existing (GSM, DECT), or specifically designed for UMTS, either terrestrial, or satellite based.

2.4. Integrating approaches

The Java Intelligent Network Infrastructure (Jini) [18], initiated by Sun Microsystems, provides a generic application environment for cooperating Java software objects and distinguishes clients and services. The goal is to ease the interworking of devices. It has been designed to handle remote objects that can be invoked from a Java virtual machine (JVM) through Java Remote Method Invocation (RMI).

The Universal Plug and Play Forum (UPnP) [19] is an industry group of companies led by Microsoft, promoting networking protocols and device interoperability standards for consumer networks, in the home, in a small business, and attached to the Internet. It focuses on LAN, USB, IEEE1394 and IrDA as physical links.

Home Plug and Play (HomePnP) [14] is an extension of the CEBus [13] and its CAL Standard (Common Application Language, EIA-600 and EIA-721) for provision of interoperability of sub-systems in personal residential areas. Its Specification details a set of behavioural characteristics for products and systems within the home that will allow them to take actions based upon the state of the home.

Home Audio/Video Interoperability (HAVi) [17], an approach of a small, closed group of manufacturers, limits its scope to communication and interaction between multimedia end-systems. The goals are comparable to Jini. As physical network, HAVi employs IEEE1394 with hot-pluggable devices, and provides an Java interface for application programmers. It distinguishes types of devices by their compliance to the system, it specifically introduces the type of a legacy device with proprietary control functionality.

The EURESCOM project P915 – Heterogeneous Inhouse Networking Environment (HINE) started to research aspects of coping with the heterogeneity of home networks, results are expected in May 2000. Our research is part of the practical task of the contribution of Deutsche Telekom.

Convergence [11] is a pragmatic approach to harmonize the EIB, BatiBus, and European Home System Association (EHSA) activities in home and building automatization. Technical details are not published so far.

The Service Location Protocol (SLP) [20] provides a scalable framework for the discovery and selection of network services, thereby replacing static configuration of network services for network based applications.

3. Architecture

Considering the situation as described above, the research task in our institute was to create an integrating platform that is able to cover most infranet technologies, to provide access towards intranet and Internet as well as telecommunication networks, and to make services available that are already provided from previous and ongoing projects [26][27][28] as well as new ones.

This platform had to be open for the upcoming tendencies. Therefore, the architecture as depicted in Figure 2 has been developed. Its modularity allows the rapid development of new applications.

The degree of proprietarity and heterogeneity of infranet systems leads to a small protocol stack, where the Medium Access is specific to the network. Often, these networks have their own logical tier, mapping network devices to logical items like virtual shared memory or virtual network variables. This logical tier is harmonized in the Link Representation Layer.

Legacy adaptors provide access to devices which are not networked at all, but provide a remote control interface. A typical example are consumer electronics with IR control.

The chips used for these control links are nowadays configurable to the protocol of a specific vendor via software.

Gateways provide access to various networks in the home or in the office. The intranet and the Internet gateway are mostly distinguished by different security restrictions, reflected by the additional firewall. The telecom gateway refers mostly to voice communication, e.g. for voice actuated control purposes, while data communication via dial-in would be routed via the internet gateway.

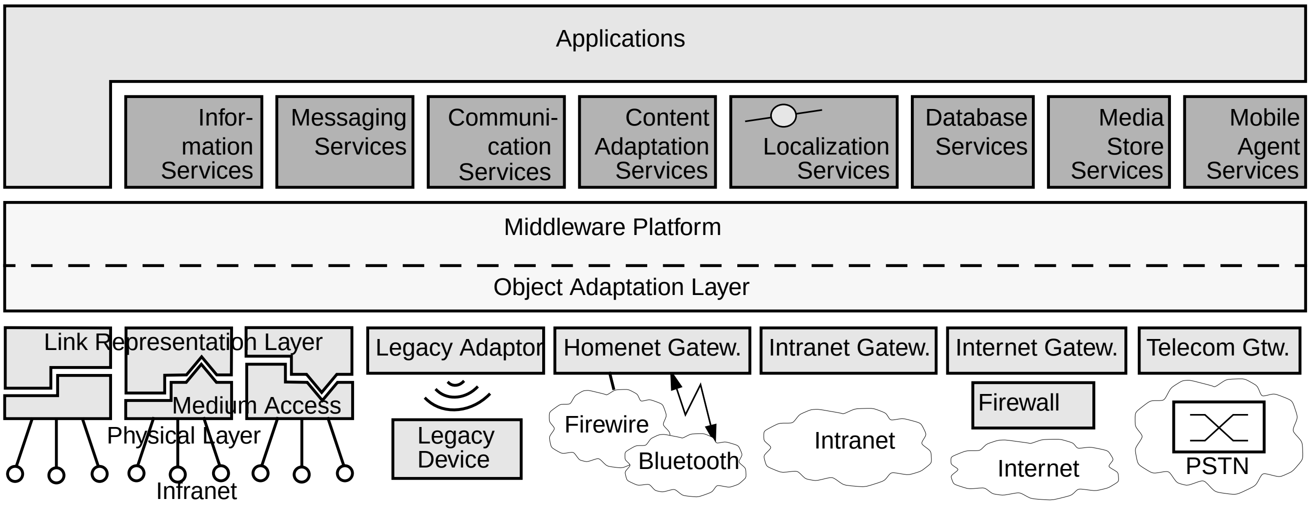

Figure 2 Architecture Overview for the Internet – Intranet – Infranet Integration Platform

In the Object Adaptation Layer as part of the middleware platform, each device would be represented by a generic class of its type (e.g. each VCR can play and record), where devices with specific profiles can inherit from this class (e.g. the Sunny VCR 123 has 20 timers and can play backwards). This ensures basic functionality any time, and additional features if the specific profile is know.

The necessity of object oriented middleware platforms as a basis for future telecommunication, defining sets of principles and components supporting openness, flexibility, and programmability, has gained general acceptance within the recent years. CORBA is our current choice for vendor openness. It provides an abstraction from the complexity of the underlying structure of heterogeneous hardware platforms, operating systems, and the difficult networking functionality.

Applications may directly access this middleware, or employ services for commonly required functionality. Many quite different applications, e.g., employ localization services of persons and objects, and use them for information purposes, for security, for communication support, or even statistics. The goal of design is to provide a modular system for a variety of applications. The advantage will be the reusability of already implemented services for further applications.

The service modules and applications are written in Java, thereby complying to integrating approaches discussed in section 2. The application programmer is relieved from details of programming the bottom-end devices and can focus on enhanced functionality.

4. Applications

To give some ideas of the possibilities of combining the modules, some application scenarios are sketched below, with examples of integrated technologies quoted in brackets in the order of appearance. Evolved from past or ongoing projects, the examples are biased, but not limited, to smart home / smart office environments.

In a location aware visitor information and guidance scenario, the office staff wears Active Badges [23][24] (transmitting to sensors in a LON network), so that the requested individual can be found, providing ubiquitous reachability. The visitor, carrying a PDA-like device, is localized by himself via the sensors, and receives directional information (via IrDA) to be displayed on the PDA [28].

In location aware access control, restriction and surveillance scenarios, time and person dependant access rules process Active Badge information (LON) and trigger door controls (EIB). Authorized persons receive paging information (messaging service) or get their phone calls rerouted (communication services) [27]. Security rules can combine database knowledge about privileges – equipment (with infrared badges and motion sensors) leaving a room together with an unauthorized person or even 'alone' can trigger alarms and close doors, while the authorized person can walk around with it.

Scenarios for usage-dependent control and billing for facilities can be built easily. As people produce heat, the number of Active Badge wearers plus passively detected room users control heating/air conditioning. The lights, shades, projection screens are adjusted to the preferences of each of the speakers (personal profile database) in a presentation. The used meeting room is automatically scheduled for next night cleaning, saving cost for cleaning unused rooms. The room usage of the ad-hoc meeting is billed to the project of the responsible person. The life cycle of the projection light bulb is monitored and, before failure, only one person is necessary to change it.

Facility management profits from centralized, remote access to control and automation networks, even for small objects e.g. in residential areas, where the metering of the used water and energy can be monitored via the Internet.

Remote home control functions can be voice actuated, thereby being accessible from anywhere in the world via telephones (PSTN). When I return from the workshop and catch an earlier plane than scheduled, the heating can be turned on from the airport. Security checks during holiday can comprise the query of the sensor status via telephone, or monitoring the video camera via Internet. Switching devices on or off via telephone delivers voice feedback and acknowledgement.

Remote, internet guided programming of video recorders allows to stay in the office longer, and to tell the system to record the football game tonight. The application receives this desire, searches the internet program guide for the most relevant broadcast, connects to the home network, transmits programming information to the old VCR (legacy device). Back at home, the preferred settings of light, temperature, shades, TV and VCR can be activated with the press of one button, or even with a voice command.

Relying on planned activities and statistical information, energy consumption is calculated and the most economical rate is negotiated (Mobile Agents) with the utilities, postponable processes can be re-scheduled.

Collecting fine-grained environmental data, such as temperature, vibration, wind velocity from thousands of sensors distributed via the countryside allows more precise prediction of weather as well as natural disasters.

Continuously collected bio-metrical data from (endangered) patients (transmitted in-house via IR by wearable sensor devices) can be used for long-term diagnosis as well as for triggering qualified emergency messages via PSTN.

5. Summary

Faced with already existing installations of heterogeneous infranet technology, we created a platform for integration of such infranets and gateways for infranet, Internet, and telephony remote access. The prototype has been built and enables the smooth migration of already existing services and creation of new service modules, leading to rapid development of new application scenarios.

6. References

[1] IEEE Std 1394-1995. IEEE Standard for a High Performance Serial Bus. - Piscataway, NJ, 1995.

[2] IEEE Draft 1394b - Long Distance Serial Bus, 1999

[3] Bluetooth Specification Release 1.0; http://www.bluetooth.com

[4] Working Group for Wireless Personal Area Networks (WPANs), IEEE group P802.15; http://grouper.ieee.org/groups/802/15/

[5] IEEE Standard 802.11. Working Group for Wireless Local Area Networks (WLANs), IEEE group P802.11; http://grouper.ieee.org/groups/802/11/

[6] Edney, J.: IEEE802.11b. The Standard for Home and Business. - in: Proc. of the Home Networking 11053, London, 14-15 Sep. 1999

[7] ETS 300 652/A2 ed.1 (1998-06) Radio Equipment and Systems (RES); HIgh PErformance Radio Local Area Network (HIPERLAN) Type 1; Functional specification. - ETSI, Sophia Antipolis, France, 1998

[8] ETSI Techn. specification TS 22.01v.3.1.0: Universal Mobile Telecommunication Systems (UMTS). Service Aspects, Service Principles. - Sophia Antapolis, France, 1997, (Version 2.0.1, August 1996)

[9] ETSI Draft 22.70v.0.0.3: Virtual Home Environments. - Sophia Antapolis, France, 1997

[10] LonWorks Engineering Bulletin. - Echelon: Palo Alto, 1995

[11] European Installation Bus (EIB); http://www.eiba.com

[12] Controller Area Networks; http://www.can-cia.de/

[13] The CEBus Standard EIA-600; http://www.cebus.org/cebus.htm

[14] Home Plug & Play; http://www.cebus.org/hpnp.htm

[15] The Infrared Data Association (IrDA); http://www.irda.org/

[16] TBR 010 ed.3 (1999-07) Digital Enhanced Cordless Telecommunications (DECT); General Terminal Attachment Requirements. - ETSI, Sophia Antipolis, France, 1999

[17] Home Audio/Video Interoperability Architecture (HAVi); http://www.havi.org

[18] Jini Technology. - White Paper. Alpha Draft 2. - Sun Microsystems: Palo Alto, August 1999; http://java.sun.com/jini

[19] Universal Plug and Play Forum (UPnP); http://www.upnp.org

[20] Service Location Protocol (SLP), IETF RFC 2165; ftp://ftp.cs.tu-berlin.de/pub/doc/rfc/rfc2165.txt

[21] Calvert, Th. H.: Home Phoneline Networking Alliance. - in: Proc. of the Home Networking 11053, London, 14-15 Sep. 1999, see also http://www.homepna.org/

[22] DiGirolamo, J.A.: The VESA Home Network. A White Paper. - in: Proc. of the Home Networking 11053, London, 14-15 Sep. 1999

[23] Harter, A.; Hopper, A.: A Distributed Location System for the Active Office. - in: IEEE Network, 8(1994)1, Jan/Feb. 1994, Special Issue on Distributed Applications for Telecommunications, IEEE Computer Society, pp. 62-70

[24] EIRIS Infrared Localization System. System Manual. - ELPAS Electro-optic Systems Ltd., Raanana, Israel, Jan. 1999

[25] Luckenbach, Th.: Seamless Integration of Infranetworks into the Internet: The I-Cube-C Project. - in: Proc. of the Home Networking 11053, London, 14-15 Sep. 1999

[26] Pfeifer, T.; Magedanz, T.; Popescu-Zeletin, R.: Intelligent Handling of Communication Media, Proc. of 5th IEEE Workshop on Future Trends of Distributed Computing Systems (FTDCS’97), Tunis, Tunisia, Oct 29-31, 1997; publ.: Los Alamitos (USA), IEEE Computer Society Press

[27] Popescu-Zeletin, Radu; Pfeifer, Tom: A Modular Location-Aware Service and Application Platform. - Proc. of The Fourth IEEE Symposium on Computers and Communications, ISCC'99, Red Sea, Egypt, July 6-8, 1999

[28] Pfeifer, T.; Magedanz, T.; Hübener, St.: Mobile Guide – Location-Aware Applications from the Lab to the Market. - in: Plagemann, Th.; Goebel, V. (Eds.): Proc. 5th International Workshop on Interactive Distributed Multimedia Systems and Telecommunication Service, IDMS'98, Oslo, Norway, Sep 8-11, 1998, Springer: Lecture notes in computer science, Vol. 1483, Berlin et al., ISBN 3-540-64955-7, pp. 15-28

[29] Long, S.; Kooper, R.; Abdowed, G.D.; Atkeson, C.G: Rapid Prototyping of Mobile Context-Aware Applications: The Cyberguide Case Study. - in Proc. 2nd ACM Intl. Conf. on Mobile Computing and Networking, MobiCom 1996

[30] Breugst, M.; Hagen, L.; Magedanz, T.: Impacts of Mobile Agent Technology on Mobile Communication System Evolution. - in: IEEE Personal Communications, 5(1998)4, August 1998, New York: IEEE, pp.56-69

[31] Siegel, Jon: CORBA Fundamentals and Programming, Domain Technology, Object Management Group, John Wiley and Sons, Inc., New York, ISBN 0471-12148-7; May 1996