УДК 681.3:621.39:51

A. Schill, Prof. Dr., A. Luntovskyy, Ph.D.,V. Vasyutynskyy, D. Gütter, Ph. D., G. Pfeifer

Approaches to the integrated network design for modern health care institutions

Nowadays, there are a lot of decisions for office communication and automation networks for health care institutions (HCI), which are conceived and designed separately. The integrated design of the networks will allow more efficient use of the hardware infrastructure and better overview of costs. The paper discusses the issues on the design of different network types. An approach to mutual using of design information is proposed. The Framework CANDY@TUD is used to solve the dedicated problems of integrated design.

В работе рассматриваются методы и инструменты проектирования интегрированных сетей с оптимизацией параметров качества обслуживания (быстродействия, режима реального времени и т.п.) с использованием средств моделирования. К основным результатам работы относятся: методика проектирования локальных сетей LAN IEEE802.3 уровня здания и кампуса, методика проектирования беспроводных сетей WLAN IEEE802.11 уровня здания и кампуса, методика проектирования сетей автоматизации зданий, проблемно-ориентированный XML-базированный язык описания телекоммуникационных сетей и сетей автоматизации, открытый инструментарий проектирования на языке Java с использованием технологий Web Services, Eclipse RCP и предназначенный для коллективных работы и совершенствования инструментов в Интернет.

1. Automation and networking in modern health care institutions

Many activities in modern HCI are highly automated, that presumes a high grade of networking between different automation systems. For example, the office communication, medical devices and building automation in a hospital are interconnected as shown in Fig.1.

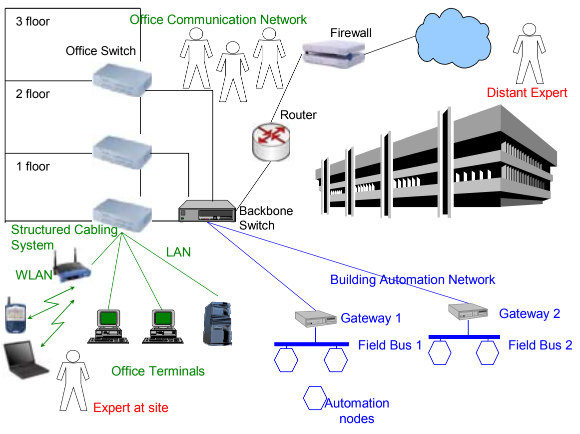


Fig.1. A networked health care institution (simplified)

This paper discusses the problems of integration of different networks in HCI on the example of CANDY-Framework. The paper is built as follows. The rest of this Chapter describes the specific requirements on networking in HCI. In Section 2 common issues on the network design with CANDY are discussed. An approach to integration of different design tools in an open framework is presented in Section 3. The approach is demonstrated on three case studies in Section 4. The glossary contains a list of used abbreviations.

HCI specific requirements to networked systems. The advantages of an automated networked hospital are effective capacity use, flexibility, rapid reaction time, reduction of operational costs and data security. The level of automation and used automation systems are very different in each case. In general, the networked systems can execute following *functions*:

- Office communication for HCI applications, incorporating the idea of a “virtual hospital”, namely:
  - patient data management: processing of orders and patient medical records, insurance and payment, archival storage;
  - capacity management: bed status and availability, patient placement, workflow automation, patient transport, medical devices allocation etc.;
  - supporting of patient diagnosis with expert systems;
  - communication with other HCI and mobile health-care workers;
  - usual office communication: e-mails, printing tasks, file transfer etc.
  - provisioning logistics: catering, medicaments etc.
- Networking of medical devices, including:
  - networked devices at the field level: health sensors etc;
  - whole building supply, like oxygen supply;
  - internal staff communication and alarms, e.g. with the help of handheld devices like PDAs or Pocket PC;
  - communication with distant health monitors, e. g. distant heart monitors over cellular phone.
- Building automation, including:
  - human access control;
  - whole building and room climate control, also referred as HVAC (“heating, ventilating and air conditioning”), which allows to reduce the energy consumption and adapt the climate to personal requirements;
  - automation of special rooms, e.g. isolation rooms with higher air pressure.

HCI networks are highly heteroheneous. Different end devices and networks types are used: office desktops, handheld devices (PDAs, Pocket PCs), wireless sensors, RFID’s for bed identification, smart cards, automation field buses, medical devices with different bandwidth requirements etc.

Another significant feature of HCI is their high demands on reliability. Some of these demands are prescribed by law, e.g. HIPAA in USA (Health Insurance Portability and Accountability Act from 1996). Hence the special requirements on networks in HCI can be derived:

- Reliability and safety, ensured by:
  - complete protection for the integrity of the network and all networked devices;
  - resiliency against disruptions of services and fast recovery by drop-outs;
  - no interference of critical and uncritical applications.
- Security
  - control the access to patient and financial data;
  - secure wired and wireless network communications.
- Flexibility and scalability, allowing easy integration of:
  - existing medical devices and automation devices in one system;
  - office applications in global information networks;
  - new devices to keep pace with growth of networked systems for a proper time period (10-20 years);
  - voice-over internet protocol (VoIP) for telephony applications like voice and fax mail
- High capability demands:
  - bandwidth demands to support large file transfers, video transmissions and dependable transmission of high-bandwidth telemedicine services;
  - real-time demands like guaranteed data transmission time or message delay.
- Easy administration, support and management to optimize IT resources.

The diversity of the automation devices and office applications with different functions makes the network organization in a hospital to a challenge. The effective using and integration of heterogeneous devices can be supported through the integrated design of the hospital networks.

2. Design framework for office communication and automation networks

Architecture of the network design network CANDY is given on Fig.2. The development paradigm for CANDY includes the use of plug-ins, loose tools and components coupling, open projects with plug-ins and web services-ready functionality. Different views on integrated office communication and automation networks are considered, i.e. topology with use of structured cabling and WLAN-routes, cost bills, performance and QoS analysis [1-5]. The integration of the tools is ensured by the object manager and the project manager, unifying the project work flow, using common object model described in ***NDML***, a XML-based problem-oriented language. The generalized structure of NDML is given in Fig.3. NDML like each *ML (mark-up language) has flexible and extensible structure language. There are the following important groups of NDML elements:

- ***Fundamentals:*** basic web standards like XHTML, HTML, XML, XSL, XSLT, Xpath.
- ***Basic Layout*** with declarative tags for description of network components, cabling system and indoor/outdoor radio network routes (so called ***RadioNDML*** [1,5]) as wells as further specific *ML extensions.
- ***Extensions:*** XQuery, XForms, SMIL, BPEL4WS. They allow better work flow control and data mapping.
- ***Design workflow*** description tags.

The brief characteristics of available CANDY tools are listed below (refer Fig.2).

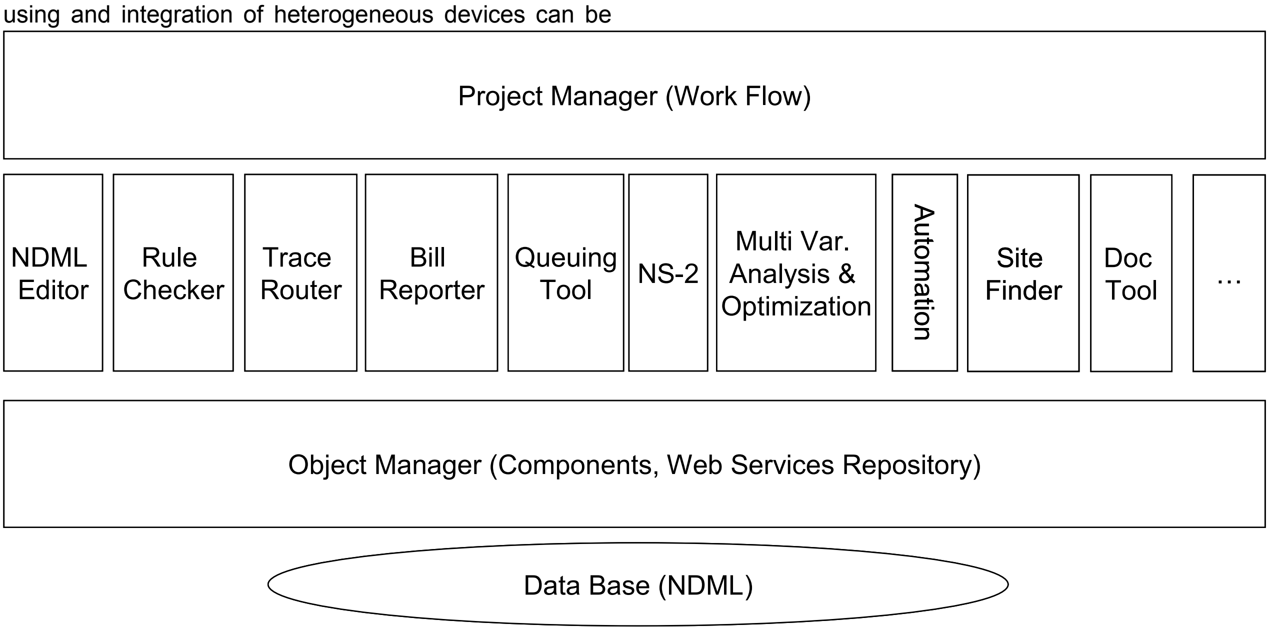


Fig.2. Extensible CANDY architecture

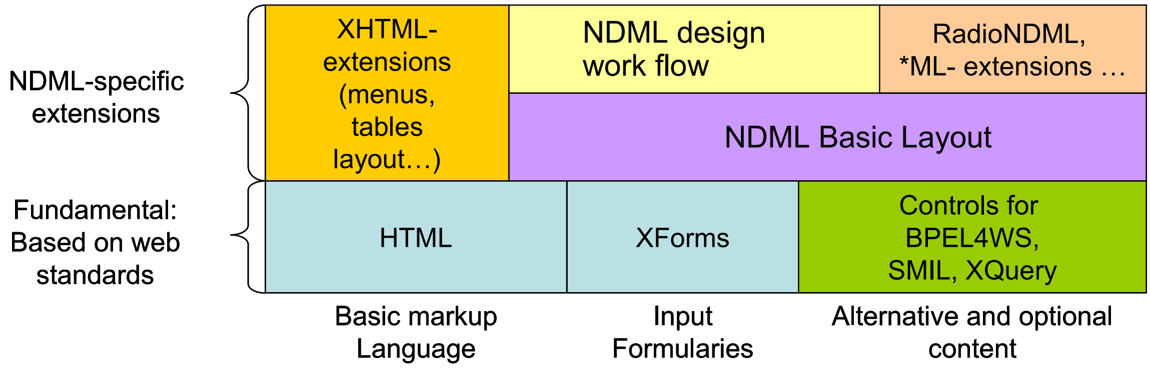


Fig.3. NDML as integration component

1. ***NDML Editor*** provides the graphical input of building contour and campus map as well as office communication and automation network (PC, gateways, routers, switches, hubs, AP, cables, automation nodes etc.).
2. ***Rule Checker*** controls the common design rules like network configuration, use of network components (swiches, routers etc.) with coupled transfer media (fiber optic, cooper cables, radio routes) as well as further workload constraints
3. ***Trace Router*** allows optimization of tracing and implementation of structured cabling system at the building for Ethernet LAN IEEE802.3 with considering of wireless routes via WLAN IEEE802.11.
4. ***Site Finder*** enables WLAN Access Point constellation optimization.
5. ***Queuing Tool and NS-2 front end*** facilitate the detailed performance analysis for complex networks (see [3]). Asymptotical prediction of network behavior (throughput, latencies) is made via ***Queuing Tool***. Accurate performance and QoS (data rate, delays, and jitter) simulation for TCP/IP protocols is carried out via ***NS-2 standard freeware simulator*** with ***NDML front end***. A possible scenario of simulation is shown in Fig.4.

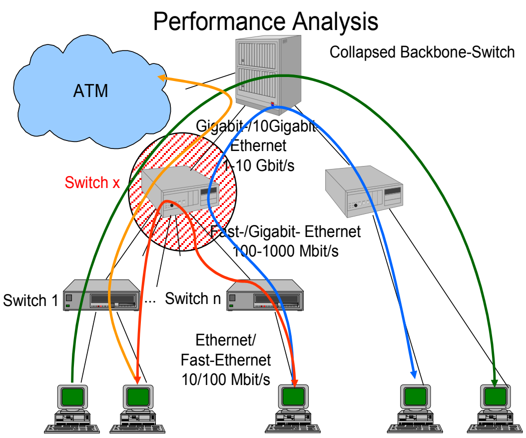


Fig.4. Scenario for performance analysis

6. ***Bill Reporter*** generates the overview of the costs of the whole system.
7. ***Multivariate Analysis and Optimization block*** is aimed to prediction of network performance and increasing of "performance/cost" –ratio.
8. ***Doc Tool*** is aimed to consistent retrieving of distributed project data for CANDY in NDML descriptions, which can be mapped on data bases as well as other target formats like PDF, HTML etc. and persistent backup at Repository of CANDY-specific objects, components and Web Services.
9. ***Automation network design tool*** integrates the automation issues into CANDY framework. It is examined in the Section 4.2.

3. CANDY as open integration tool

In this Section, the aspects of implementation of the CANDY Framework as open integration tool are considered. The CANDY environment consists of the different CANDY tools (given in Fig.2) that are able to contribute certain parts of the work in a network design project. For these tools a technique is needed which allows to use them in a convenient environment. Such environment should allow:

- distributive tool development;
- on-demand combination of components for different purposes;
- reuse of existing components.

The specific encapsulated CADs interfaced to specific network design problems (WLAN indoor decisions design, WiMAX outdoor decisions design, real time automation networks design etc.) can be created on this flexible basis. After testing of some different possibilities only two competitors were chosen: Web Services and the Eclipse RCP (Rich Client Platform).

CANDY open source project as Web Services. Web services is a distributed computing model, based on asynchronous messaging where messages are composed using XML. They support dynamic application integration over the web, which is an important advantage in the case of CANDY, because producers of different network components might want to provide particular components to their customers. Besides dynamic integration, web services also support "on-the-fly"-software creation using loosely coupled, reusable software components which are using the Internet to exchange data and provide service to each other.

CANDY open source project as Eclipse RCP. Eclipse is a universal platform for integrating development tools. It is quite common for use as integrated development environment for software engineering. It turned out that many workbench components are not IDE specific but also can be used in advanced desktop applications which have quite similar demands, like open and extensible architecture, an efficient, customizable, and comfortable user interface, product branding, update support, e.g., for security updates, an integrated help system, support for different languages, and many more. The RCP, Rich Client Platform (Fig.5), has an open and extensible architecture. Applications can by customized using layers of plug-ins. These plug-ins are based on a runtime environment which provides good integration with existing desktop tools, lower server loads, offline execution, and local data access. The good performance is reached by using native GUI components of the OS they run on. Furthermore it supports lazy loading of components, versioning, and dynamic detection and invocation of components.

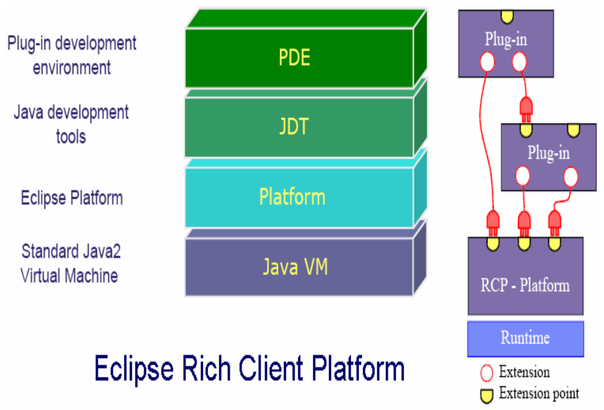


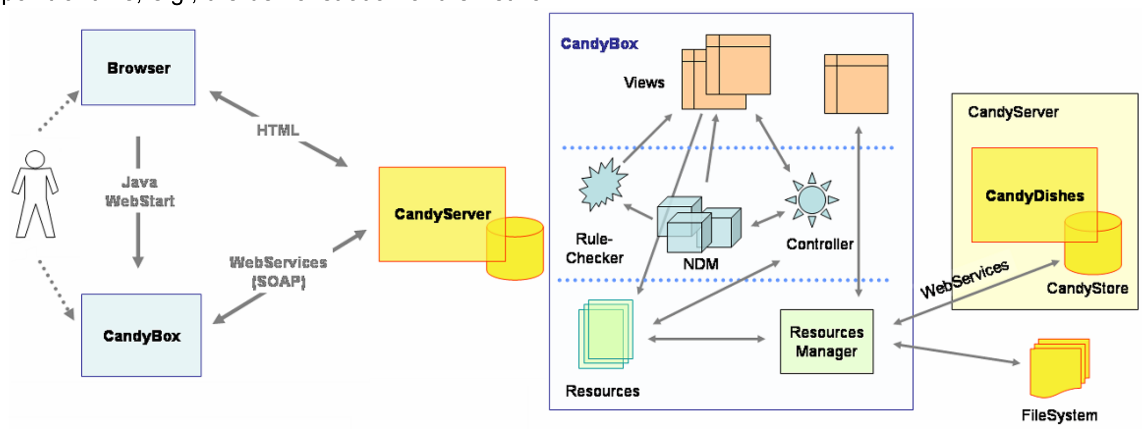
Fig.5. ECRP Architecture (www.eclipse.org)

Web services versus RCP. The advantages of Web Services are that service providers are able to charge their customers per use. The implementation details of certain tools are well protected since those tools can be located at the producer site behind a curtain of abstraction via SOAP. A disadvantage is that the user has to be connected to the Internet to use these services. This is an issue in terms of availability of services and cost of connection and use. Furthermore a service provider is not likely to guarantee the availability of the service. So if a customer desperately needs a certain service at a certain point of time, e.g., the demonstration of the network performance as part of a presentation for her customers, it might not be available.

Organizational principles for CANDY RCP-applications. Each CANDY tool consists of a *CandyBox* and can be also extended via a ***CandyServer***. Furthermore, there are other smaller tools, for instance, an *Installer* for Windows (Fig.6).

As programming paradigm MVC, «Model – Views – Controller» is used [6-9]. ***NDM, Network Design Model*** is then a model of a designed or existed network and simultaneously a special ***CandyResource*** (Fig.6). The ***NDM*** is described in the CandyBox as a set of cooperating Java-classes. Therefore NDML is its persistent form. ***CandyBox*** is a RCP-based application and also can run independently from ***CandyServer***. ***CandyBox*** offers a graphic GUI for the ***NDM*** and other ***CandyResources***. ***CandyPlatform*** is the central element of ***CandyBox***, like, for instance, ***NDM*** for resource management. Graphical editor or other RCP-application can be extensible and adaptable. ***CandyBox*** can be simply extended for new functionality. ***CandyServer*** offers, in the first place, an extended resource for ***CandyBoxes***. ***CandyResources*** are the objects (also components and Web Services) for network description, planning and implementation. ***CandyResources*** can be simple files, NDML-files, pictures, directories or meta-objects like „Project“, „User“, “Configuration” or „Workflow“.

The objects and components can be created or assigned by ***CandyResources***. ***Resource Manager*** manages and provides necessary synchronization with, for instance, ***CandyServer. CandyServer*** is originally based on Tomcat Application Server with interface to a data base but will be step-by-step completed for routing of SOAP-connections. ***CandyBox*** uses ***CandyServer***, first of all, for obtaining of ***CandyResources***. ***CandyServer*** (correspondently ist Data Base ***CandyStore***) serve for necessary management. With use of this MVC-paradigm (see Fig.6) the Controller manages Views and Resources for all RCP-Applications like, for instance, ***CANDY Rule Checker***.



(a) Java tools communication **(b) Encapsulated design tools**

Fig.6. CANDY Framework: RCP applications

4. Case Studies

The open architecture of CANDY allows the design of heterogeneous demands and techniques like different transmission media, different functions and representation forms. Next Sections demonstrate this possibility on three representative case studies: design of wireless access, integration of automation and office networks and adaptation of information presentation for different users and end devices.

4.1. WLAN Design

WLAN design with ***Site Finder***, a part of CANDY, involves the optimization of placement of internet access points (AP) in a building. ***Site Finder Drop Algorithm (SFDA)*** and ***Multi Color Ink Spot Algorithm (MCISA)*** are used as the simulation methods for indoor WLAN based on the building layout. Site Finder carries out (Fig.7):

1. Import and re-scaling of building contour or campus map.
2. Specification of diverse wall types, using the predefined macros for different materials).
3. Specification of AP types, AP constellation and configuration on the building contour (campus map).
4. Visualization of existed networks with direction of RF coverage and signal quality.
5. Simulation of approximated AP constellation using Site Finder Drop Algorithm.
6. Specification of user profiles and user placements on the building contour (campus map).
7. Simulation of approximated AP constellation based on the Multi Color Ink Spot Algorithm.
8. Cellular structure creation on the basis of Multi Color Ink Spot Algorithm (Channel Assignment).
9. WLAN verification, installation costs calculation and documentation into CANDY with use of Bill Reporter.
10. Data description with the help of NDML extension.

SFDA combines considering of physical signal propagation conditions with use of empirical models and graph based approaches to buildings geometry (drop heuristics). The mentioned models include the simple, as well as relatively complicated models for propagation prediction like: clearance by Fresnel, propagation by Okumura-HATA, COST231/HATA, COST231/Welfish-Ikegami. Use of optical models and finite elements models is hampered due to their significant complexity, though they whould give more accurate presentation of signal intensity. ***MCISA*** [16] considers the physical propagation conditions, using the specific algorithms for Channel Assignment via graph coloring heuristics and for Load Balancing via room coloring process (see Fig.7). An initial constellation of AP due to signal quality (SFDA) is optimized via workload considering (MCISA). The architecture of ***Site Finder*** is shown on Fig.8.

4.2. Design of automation networks

In this Section the issues on integration of the automation networks of different types in office communication infrastructure will be discussed.

Today the building automation systems fulfill diverse functions like climate control (heating or cooling, lightning or air conditioning), human access and security control etc (see Fig.9). In most cases the functions are realized in a de-central way, in distributed intelligent nodes (sensors, controllers, actors, monitors), which communicate with each other over field bus. In last years the building automation intrudes the traditional sphere of office communication networks to become web-enabled, according to the concept of a *smart home*. The possible variants of the integration of automation networks in office communication are discussed below.

Building automation design. Nowadays, the building automation networks are designed using standardized tools and data bases. These tools enable processing and storage of the design information at all three levels of building automation: field (sensors, actuators), automation (controllers, gateways) and management (configuration, diagnosis) level.

Most automation networks have the interfaces to Ethernet. These may be simple gateways (Ethernet adapters, IP-bridges), tunneling the field bus packets through Ethernet, or web servers, allowing more complex services.

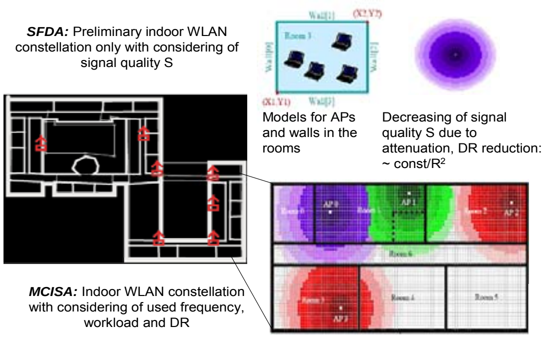


Fig.7. Design via Site Finder

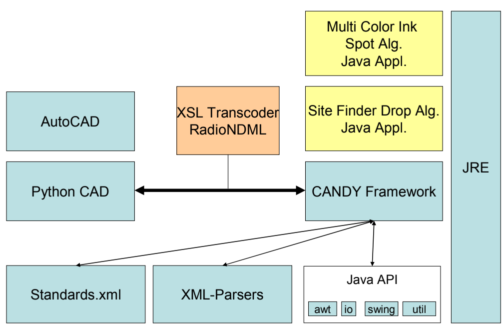


Fig.8. CANDY Site Finder as Java-application

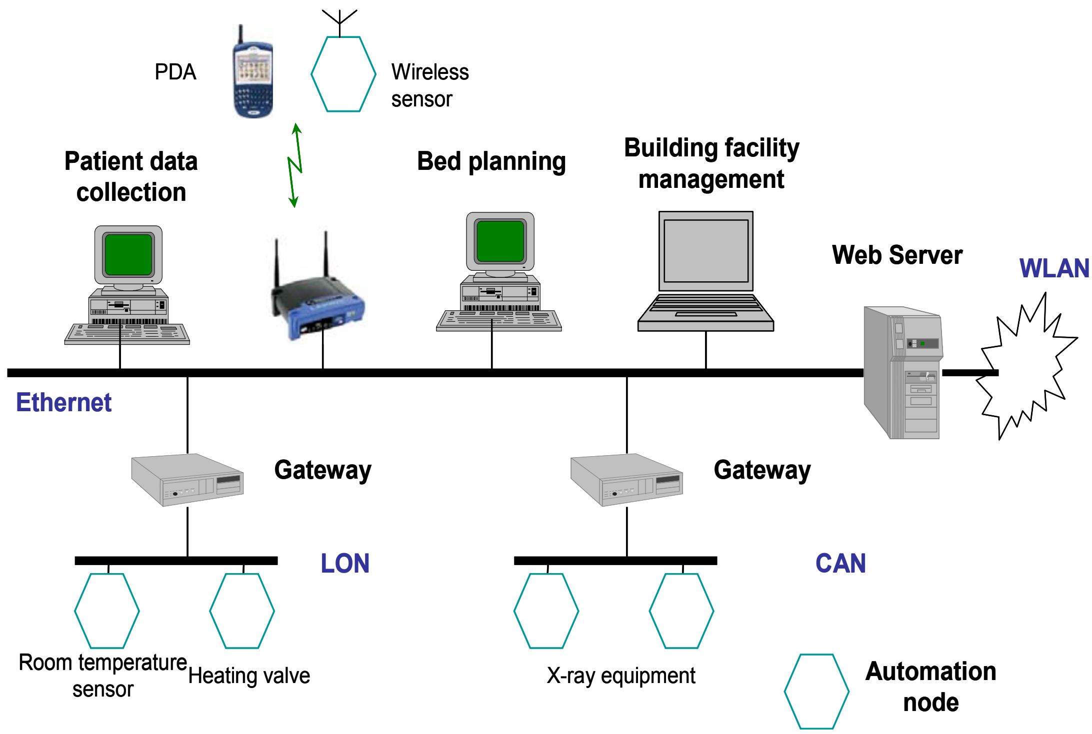


Fig. 9. Typical components of an automation network in hospital

The *management level* devices are most uncritical from the view point of using with office communication, since they do not influence normal operation and availability of the automation systems. The *automation level* devices and office backbone have similar requirements on the availability and life time and can be smooth integrated.

Using of the office infrastructure at the *field* level is more problematic. The field devices must be more reliable and should work in an autonomous way. Also the real-time requirements such as message delays (min, mean or max delay or delay distribution) are much harder. For example, in closed control loops with small time constants the additional delays may lead to the loop instability ([10-15]). Excessive delays are very critical in fire alarm or access control systems. To connect two field devices, the tunneling of the field bus packets in TCP/IP is used, that leads to large overhead, since IP packets are larger, converting and transmission time appear as additional communication delays, which are hardly predictable. However, the Ethernet communication can be used for the control with large time constants like heating.

Further, hardware for integration of field devices in Ethernet/IP is available, like:

- Special bus clamps allow the integration of the field bus nodes in Ethernet.
- Power over Ethernet (POE), an emerging technology that allow to supply the external devices with 48V DC and save the dedicated power supply cables.
- Wireless transmitters can be used as base stations for wireless sensors.

Different variants of interconnection of office and automation networks are shown in Fig.9.

The integration of the gateways in already available office networks is more preferable to the laying of new cables and organizing of the dedicated Ethernet networks, presuming that reliability demands are met. It would allow saving the costs caused by double infrastructure. Besides Ethernet, modern technologies provide further types of such infrastructure that can be used mutually. So, Power Line Communication technologies (PLC) allow using the power supply for data transmitting. The wireless transmitters can be used for the office communication as well as the base stations for wireless sensors.

The overview above showed the necessity of the integrated design of computational and automation networks. Moreover, there exists a general trend of involving further design tools in design of automation networks. For example, the information of building layout obtained from CAD tools is used for the network layout planning based on the interchange format IFC ([11,12]). Such integrated design can be used by the different experts in different steps of the automation system life cycle, e.g. in integration of building automation in existing office network. In this case the layout of office network is used to define the optimal configuration of automation network. In its turn, the additional network load caused by automation networks should be evaluated.

The need for integration of diverse tools in this design tasks is evidential.

Integrated design of office communication and building automation networks. It is clear, that the first principles of design are same for office and automation networks. The distinctive feature of the automation networks is their more deterministic functioning and special real-time requirements. Creation of a "universal" tool that would include all the design aspects on so different network types seems to be rather hypothetical due to economical (diversity of commercial tools and formats) and ergonomic considerations (their complicated handling).

More realistic is the bridging between existing design tools through creation of appropriate interfaces with the help of NDML. The following tools of CANDY can be used simultaneously for automation and office network design:

- NDML Editor to edit the geometrical layout. Example: check if the automation node can be attached to the network (is there an appropriate cable or should we a new one be laid?)
- Rule checker for checking of laying rules. Example: prove if one node can communicate with some other node over network (physical access (cables), fire-walls, real-time constraints (are the communication delays acceptable for these nodes)?)
- Queuing tool for evaluation of network load. Example: does the additional load of automation nodes influence the network critically?
- Bill reporter for cost analysis and linear optimization. Example: There are two LON segments. Is it more economical to install two Ethernet adapters or one LON switch with additional cables to connect them? Also layout should be incorporated in this analysis.
- Documentation that allows more effective network management.

The following information should be considered additionally to traditional view points (extensions in NDML):

- Real-time requirements. These requirements play the most important role in node-to-node communication. In distant monitoring, the real-time requirements are soft, since no close-loop control is made in that way. However, the proper maximal time limit should be guaranteed.
- The traffic behavior of automation nodes is more deterministic then that of conventional computer user. This property can be used for better evaluation of in queuing analysis.

A principal organization of information interchange between two design tools is shown in Fig.10. The following project data can be imported from automation system design tools:

- Topology of the automation network. The Ethernet gateway in the network can be extracted.
- The properties of networked automation nodes can be extracted from node profiles. The selectivity and information filters are important. Only necessary features should be imported to avoid the flooding with superfluous information. On the other hand, some security relevant information should not be released to other persons.

The necessary information can be imported from the third party tools, for example the geometrical building layout (CADs: AutoCAD, IFC).

Further problems should be considered on OSI-layers 2-4½ as well as on application levels:

- Security. The automation systems are more critical to security.
- Safety and reliability.
- Integration of web based services.
- Lifetime of the components.

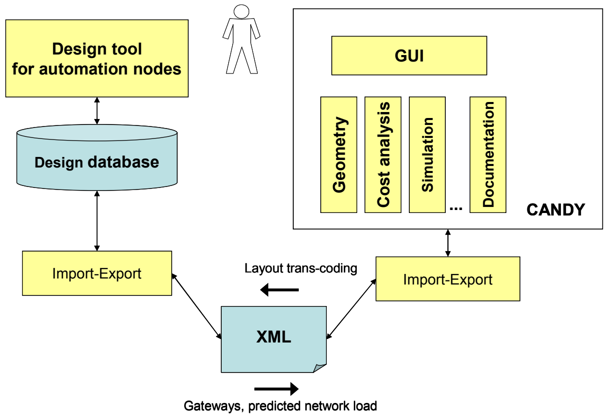


Fig.10. Information flow between tools

4.3. Automation Mobility Portals

Different users and end devices are available in a hospital, requiring different information types and representation forms. ***Automation Mobility Portal*** (AMP) facilitates the mobile or wired network access, adapting it to the needs of modern HCI. It is based on XML/Java-technologies [6-9], as shown in Fig.11. Distant medical practitioners, automation experts or IT-specialists as well as the experts at site (communication via LAN or WLAN) are able to read and modify critical automation data (see also Fig.1). Different specialists like medical practitioners, automation experts or IT-specialists are using PC, PDA or smart-phones in the different ways.. The web content is adapted to the end-devices resources and representation availabilities. Fig.11 presents the software architecture of AMP, which enhances the web portals with the invariant support of different mobile and stationary end device (PCs, notebooks, PDAs or smart phones) [7]. Therefore, due to XML-Transcoding into target formats (HTML, XHTML, WML), the design data can be invariantly represented on mobile end-devices with limited screen resolution and navigational abilities.

Conclusions

Distinguishing features of design processes of automation and communication networks are investigated in this paper. The common requirements on the modern HCI networks are examined. The integrated design of building automation, medical and office communication networks contributes to creation or more efficient use of the infrastructure at HCI. The discussed open CANDY tools offer to designer teams the possibility of mutual (tele-)working on such complex projects. Three case studies are examined, namely design of WLAN, integrated design of building automation and design of the mobile web portal.

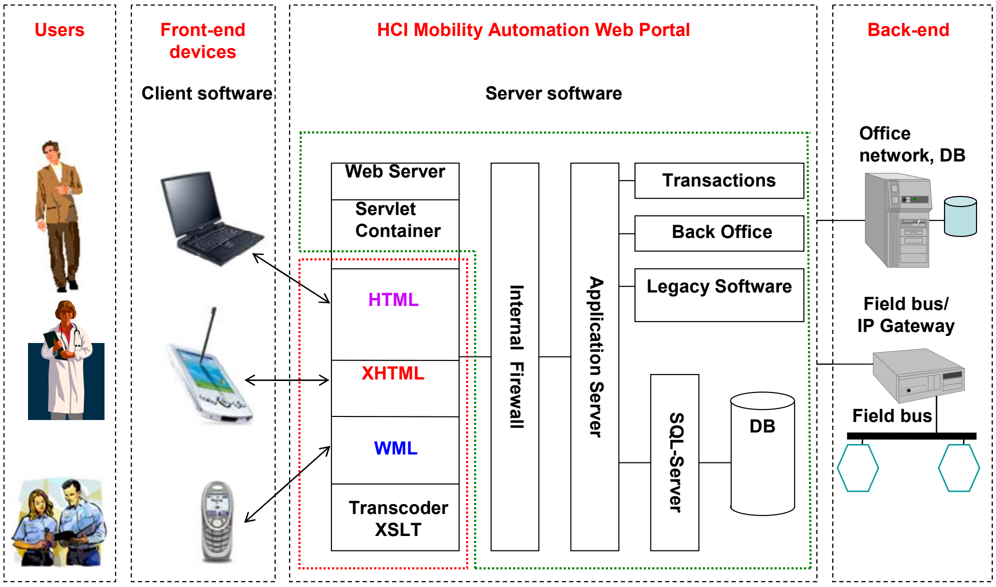


Fig.11. Automation Mobility Portal Software Architecture (Schill, 2004)

References

1. CANDY@TUD design tool project: http://www.rn.inf.tu-dresden.de/scripts_lsm/Lehre/candy/index.html
2. Luntovskyy, A., Schill, A., Gütter, D., Pfeifer, G., Panchenko, A.: **CANDY: INTEGRATED ENVIRONMENT FOR NETWORK DESIGN**; *The 8th World Multi-Conference on SYSTEMICS, CYBERNETICS AND INFORMATICS (SCI 2004), July 18-21, 2004, Orlando, Florida, USA, Vol.3, pp. 252-257, ISBN 980-6560-13-2* // Dresden University of Technology Faculty for Informatics, Institute for System Architecture, Chair for Computer Networks
3. Luntovskyy, A., Schill, A., Pfeifer, G., Gütter, D., Panchenko, A., Vasyutynskyy, V.: **COMPUTER NETWORK MODELING AND ANALYSIS USING XML-DESCRIPTIONS;** *The 9th World Multi-Conference on SYSTEMICS, CYBERNETICS AND INFORMATICS (WMSCI 2005), July 10-13, 2005, Orlando, Florida, USA, pp. 283-288, ISBN 980-6560-54-3* // Dresden University of Technology Faculty for Informatics, Institute for System Architecture, Chair for Computer Networks (англ.)
4. Luntovskyy, A., Gütter, D., Schill, A., Winkler, U. **Concept of an Integrated Environment for Network Design**// IEEE CriMiCo Conference, Sevastopol, Sept. 2005, pp. 959-961 (ISBN 966-7968-79-0)– 15 Міжнародна Кримська конференція КриМіКо 2005
5. Luntovskyy, A., Gütter, D., Schill, A., Winkler, U. **Design Particularities for Wireless Networks**// IEEE CriMiCo Conference, Sevastopol, Sept. 2005, pp. 955-958 (ISBN 966-7968-79-0) (англ.) – 15-та Міжнародна Кримська конференція КриМіКо 2005.
6. Schill, A. **Service-Oriented Architectures: Potential and Challenges**// IEEE CriMiCo Conference, Sevastopol, Sept. 2005, pp.16-18 (ISBN 966-7968-77-4) (англ.) – 15-та Міжнародна Кримська конференція КриМіКо 2005
7. Hübsch, G., Springer, T., Spriestersbach, S., Ziegert, T.: An Integrated Platform for Mobile, Context-Aware, and Adaptive Enterprise Applications; *Wirtschaftsinformatik 2005 (WI2005), Bamberg, Germany, Feb 23-25, 2005*
8. Eclipse RCP: http://www.jugs.ch/html/events/slides/041012_ERCP.pdf
9. Web Services: http://www.w3.org/2002/ws/
10. W.Kastner, G.Neugschwandtner, S.Soucek, M.H. Newman, "Communication Systems for Building Automation and Control". Proc. of IEEE, Vol. 93, No. 6, June 2005, pp.1178-1203
11. M.Neugebauer, J.Plönnigs, K.Kabitzsch, P.Buchholz, "Automated Modeling of LonWorks Building Automation Networks", in *Proc. WFCS2004* IEEE International Workshop on Factory Communication Systems, Vienna, Austria, September 2004, pp.113-118
12. Karavan, M. Neugebauer, K. Kabitzsch, "Merging Building Automation Network Design and IFC 2x Construction Projects", *22nd Conference on Information Technology in Construction*, July 19-21, 2005, Dresden, Germany, pp.575-581.
13. A.Dementjev, K. Kabitzsch, "A Consulting Module in Room Automation", Proc.TA04 1st IFAC Symposium on Telematics Applications in Automation and Robotics, Helsinki, Finland, June2004, pp.37-42
14. S. Soucek, T. Sauter, "Quality of service concerns in IP-based control systems". IEEE Transactions on Industrial Electronics, Volume 51, Issue 6, Dec. 2004, pp. 1249 – 1258
15. LonTalk Protocol Specification (1994). 3.0 ed. Palo Alto: http://www.echelon.com
16. Helena Unger, Djamshid Tavangarian, Steffen Silberbach. Simulationsbasierte Planung von Wireless LAN HotSpots/ Institut für Technische Informatik, Fachbereich Informatik, Universität Rostock, 2003.