Domotics and Infomobility in the ASK-IT Project

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Abstract

While the main objective of the ASK-IT project is to increase independence of mobility impaired users during trips, the integration of a domotic system is a valuable addition. It helps to make the ASK-IT services more accessible when the user is at home, taking into account the user's specific impairment. Additionally, domotic systems also increase the feeling of safety and security by letting the user check the state of their home while being on the move.

As of today, no common standard for a domotic system has been established. Instead, many different, typically incompatible systems are competing in the market. Also when considering technical aids for mobility impaired users, there are various isolated solutions available. This situation presents a massive challenge to the ASK-IT project. Taking decision for a single existing domotic system may rule out a number of useful devices. Because the whole ASK-IT platform is not specifically targeted for domotic applications, it is also not to be expected that third party manufacturers will adapt their devices to work with the ASK-IT platform in the immediate future.

Another hurdle is that installing new wires to connect domotic devices is not always an adequate solution. Using radio frequency or power-line (“no-new-wires”) is often more applicable, reducing installation effort and costs.

In this paper, we present a domotic system which addresses these issues. The system employs a high speed, high complexity IP Backbone running an open protocol for inter-device communication. A Residential Gateway interfaces the IP Backbone to the internet and to the ASK-IT services. Interface units (Local Control Units) are used to integrate various domotic devices into the IP Backbone and furthermore into the ASK-IT platform.

Keywords

Infomobility, Domotics, Home-Automation, Interoperability, Mobility Impaired Users

1 Introduction

1.1 Why Domotics?

In general, domotic systems will help to increase the quality of life of mobility impaired persons (MI). Today, “off-the-shelf”-systems are already available to assist in daily life, e.g., to turn on lamps when entering the room or to generate a warning (using acoustic signals or visual messages) when leaving the home while the stove is still turned on. Less obvious domotic systems are found in numerous houses, such as air conditioning and heating systems controlled by a central console.

For mobility impaired users, there are many specific solutions to help them inside their homes. For example, persons unable to move their upper limbs can use their voice to control their environment. Blind users could obtain information on their home through spoken language coming from a speech generating device.

Combining the ASK-IT internet services with a domotic system generates a considerable amount of synergy. For example, the domotic system may use the ASK-IT platform to expose its functionalities to the user on the move and to obtain centralised information on the users preferences. On the other hand, a domotic system may enable ASK-IT to offer services using domotic devices and user interfaces.

To illustrate how the interplay between ASK-IT internet services and the domotic systems works, two different cases will be distinguished: Either the user is at home or the user is on the move.

1.1.1 The “at home” Perspective

While the user is inside his home, the domotic system might offer a number of enhanced features based on the ASK-IT platform. For example, graphical displays could be used to remind the user of appointments or of other daily obligations, like taking medicines. Alternatively, the information could be provided by a speech generator or other means, depending on the user's abilities. Information may not only flow from the ASK-IT platform to the domotic system, but also the opposite direction offers many benefits. The devices inside the home may be used to perform simple monitoring jobs, informing the ASK-IT platform about certain events. For example, an electronic door could recognize when the user leaves his home. The ASK-IT platform could automatically initiate a connection to the user's mobile phone or PDA to offer travel assistance such as time tables for public transport or options to call a taxi.

In a graver scenario the domotic system may report to the ASK-IT platform when a user has not used any domotic device for a period of time while being at home, because this might indicate a case of emergency. After failing to contact the user, the ASK-IT platform would initiate an emergency plan, e.g. by calling a nurse to look after the user.

1.1.2 The “on the move” Perspective

Being on the move, the user is able to communicate with the ASK-IT platform using a PDA or mobile phone, to see what is happening inside his home and also to control the domotic devices through the ASK-IT web interface. For example, after leaving his home, the user may check if he has turned off the stove or if the windows are closed (common questions not only

for mobility impaired users). Additionally, he may alter device states. Another example is that the user turns on the heater before coming back home. The domotic system could also send messages to the user's PDA or mobile phone automatically, for example to remind him that he left his home while the windows are still open.

Features provided by the interplay of ASK-IT and domotics are increasing the perceived and the actual safety of the user. Being able to check the state of the home could remove worries from travellers. Furthermore, the ability to control domotic devices by remote could prevent real danger such as a forgotten stove that can be turned off.

1.2 State of the Art

A large variety of different and mostly incompatible domotic systems exists today [3, 5], such as Konnex/EIB [9], LonWorks [7], LCN [14] or HS485 [4]. Every domotic system specifies its own physical communication media and communication protocol. In the area of systems for mobility impaired users, many isolated and incompatible solutions exist on the market.

Furthermore, numerous isolated, but nevertheless "intelligent" and communicating systems are already installed in modern households, like heating or air conditioning systems or remote control sets for “brown goods”. Because every system uses its own standard, integration becomes more and more necessary.

For the installation of new systems, wireless and power-line solutions are preferred (“no-new-wires”), because in most cases existing houses have to be retrofitted. As for wireless solutions, there are many different standards with varying complexity, e.g., Bluetooth [6], Zigbee [12], or Z-Wave [13]. Examples for power-line solutions are Powernet EIB (Konnex PL110) [15], serve@home [10], or X10 [16].

2 The ASK-IT Approach

Domotic systems integrated into the ASK-IT platform have to meet the following requirements:

- they have to be affordable,
- it has to be possible to install them without installing new wires in existing homes,
- they have to enable the integration of existing domotic systems and devices,
- they have to support an easy maintenance procedure.

Next to the plain hardware setup, a domotic system needs a considerable amount of logic to control all the devices inside the home. This control logic might range from very simple scenarios (e.g., "turn on the light when the switch is set to 'on'"), to very complex behaviours - especially when considering the features provided by the ASK-IT platform.

Two different types of control logic will be pointed out:

- simple Boolean logic (e.g., turning on a light when a switch is set to 'on'),
- event based logic (e.g., motion detection controlled lights).

The control logic required for the domotic system has to be formulated and implemented. Basically, there are two considerable implementation options: either the logic can be centralised in a single unit (e.g. a PC) or it can be distributed among different devices, meeting certain capability requirements.

Centralised systems are easier to maintain than distributed systems. The catch of centralised systems is always that damages in case of malfunction are severe: when the central server fails, most of the domotic devices will not work as expected. In general, failures in distributed systems cause less damage: the failure of a single control unit would only affect a part of the house (e.g. a single room), which is a much more acceptable situation than the whole house malfunctioning.

For the integration of domotic systems into the ASK-IT platform, we propose a multi-level solution. The core of this solution is an IP-based backbone network (the *IP Backbone*), interfaced to the ASK-IT platform using a gateway (the *Residential Gateway*). Network adapters (the *Local Control Units*) are responsible for the integration of non-compatible domotic systems and devices as well as for running the control logic of the domotic system.

2.1 Global Network Topology

From a global perspective, the entire ASK-IT network falls into two separate networks: a *Wide Area Network* (WAN) and a *Local Area Network* (or *Domotic Network*). The Wide Area Network is used for the ASK-IT services, while the Domotic Network is used to interconnect the domotic devices (e.g., white or brown goods, media centres or PCs). A gateway – the so-called *Residential Gateway* – binds both networks together (see Figure 1).

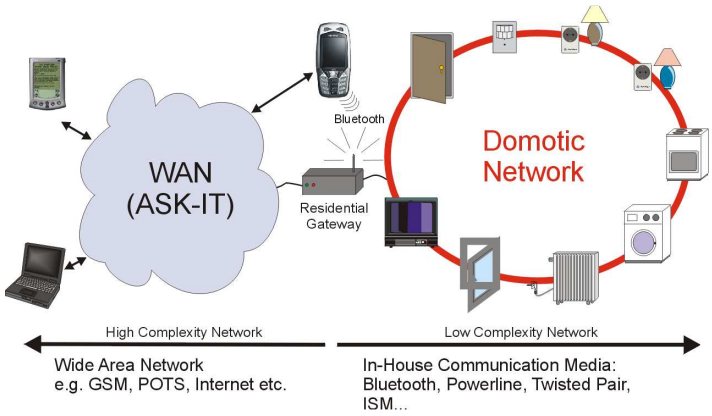

Figure 1 - ASK-IT Global Network Topology

The communication flow is as follows: If the ASK-IT platform has to query the current state of a domotic device, it has to contact the Residential Gateway. The Residential Gateway forwards the request to the specific device in the domotic system. The response of this device will be sent back to the Residential Gateway, in order to be usable by the ASK-IT platform. The inverse mechanism is applied when a domotic device needs information from the ASK-IT platform.

2.2 IP Backbone

The basis of the domotic network is provided by an *IP Backbone*, using the *Internet Protocol* (IP). The IP technology has a number of advantages, making it also very suitable for home networks:

- Products using different physical media are available on the market (e.g., twisted-pair, power-line etc.),
- it offers high bandwidths, so it might also be used for multi-media services,
- IP is a mainstream technology, bearing inexpensive products with an excellent availability.

A major requirement for our domotic system is that it can be installed without installation of new wires. The IP technology offers a variety of solutions: the backbone network may be implemented either by wireless communication (WiFi), power supply wires (Powerline), or

by twisted pair Ethernet (Ethernet might be installed in newly constructed houses from the beginning).

The high communication bandwidth provided by the different communication media is another beneficial aspect of IP based networks. While the majority of applications in the domotic area will generate only small messages at low frequency, bandwidth intensive multimedia applications are becoming more and more common. In context of the ASK-IT project, it would be possible to illustrate travel routes as animated movie clips, streamed from the ASK-IT server to a terminal inside the home by using the same network infrastructure.

Because IP is a mainstream technology, products using wireless or power line communication are available on the market, offering a very good availability and good prices. Consequently, it is to be expected that IP remains as a standard technology for many years to come, especially when considering the global importance it has achieved in form of the internet.

For the IP Backbone of the Domotic Network, an open XML/SOAP [11, 17] based protocol will be used, such as DomoML [2]. Domotic devices supporting this open protocol may be attached directly to the IP Backbone. This includes the Residential Gateway as well as other complex devices such as media centres.

2.3 Local Control Units

In order to incorporate devices or domotic systems to the IP Backbone, interface devices (*Local Control Units*, LCU) are inserted into the network infrastructure. The major tasks of the LCUs are:

- to give (incompatible) domotic devices their own “identity” in the IP Backbone,
- to implement a custom-specific control logic.

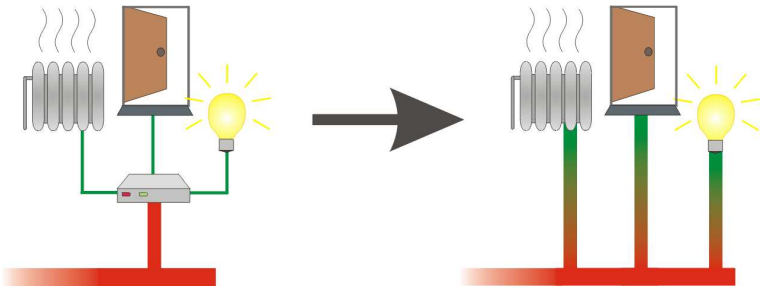

Figure 2 - Local Control Unit Interfacing Devices

An LCU provides two or more ports for different communication systems. The first port is an IP connector (*primary port*), connecting the LCU to the IP Backbone. The other port(s) (*secondary ports*) are used to attach the domotic system to the LCU, e.g., HS485 [4], LonWorks, or Konnex. The LCU manages all devices attached to its secondary port and implements an access layer, making them transparently available to the IP Backbone (see Figure 2). In detail, the LCU provides the following features:

- mapping all domotic devices (attached to the secondary ports) to unique addresses on the IP Backbone,
- making the services of domotic devices available on the IP Backbone,
- associating messages on the IP Backbone with the domotic devices on the secondary ports,
- translating messages between the XML/SOAP language (used on the IP Backbone) and the specific protocols used by the devices on the secondary ports.

While the assignment of unique addresses is a simple task, the remaining features will require specific knowledge about the domotic device. This will be implemented by a *device driver model*, encapsulating the specific communication procedures by a standardized interface. In this sense, device drivers are working exactly like their namesakes in common operating systems.

Exemplarily, we want to attach a lamp to an LCU using a simple domotic bus system. The LCU assigns a unique address to be used on the IP Backbone, and it starts a specific device driver for the lamp afterwards. Depending on the bus system, the device driver may be selected automatically by identifying the device through bus specific class or device IDs (*plug-and-play behaviour*). Alternatively, the device driver may be selected manually by the user or installer. In either way, the matching device driver has to communicate with the domotic device to expose its functionalities and properties to the IP Backbone. In case of a lamp, it may deliver the name and/or location and even an icon to be displayed on a graphical user interface. Furthermore, it forwards control messages (like *turn on* or *turn off*) from the IP Backbone to the device.

The control logic implemented by the LCU is a piece of software that when triggered by internal (e.g. timers) or external (e.g. switches) events, sends commands to the connected devices. Continuing the example from above, the control logic could wait for an event triggered when the front door is opened. It may send a message to the living room light to be turned on, and it may start a timer of one minute. If an event is coming from the light switch during this period, the timer is cancelled; otherwise the LCU will send another message to the light in order to turn it off.

2.4 LCU Implementation

The requirements on the hardware of the LCU are state of the art. The main hardware components are (1) a connector to the IP backbone, (2) one or more secondary ports for the domotic devices, and (3) a microcontroller. In contrast, the software is relatively complex. It has to provide the communication protocol, various device drivers, and the control logic. Additionally, it is a strong requirement that all device drivers and control logic may be updated in the field during system lifetime.

Our solution uses the JAVA programming language to implement device drivers and control logic. JAVA has many advantages, qualifying it for this task. Most prominently it uses a platform independent bytecode, executable on any hardware or operating system that offers an adequate runtime environment. The main components of the runtime environment are a bytecode interpreter and a core class library. Both can be implemented on the basis of compact embedded platforms [1, 8] as well as on standard PC systems. The software components running on top of the bytecode interpreter (like the device drivers or the control logic) can be run independently of a specific hardware or

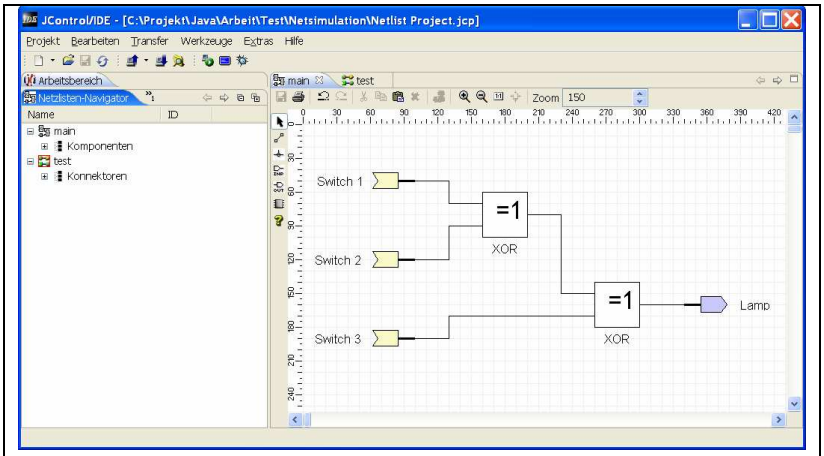

Figure 3 – Jcontrol/NetEdit

operating system. Thus, a device driver may be uploaded to completely different hardware platforms – an important prerequisite for software reuse strategies. Additionally, JAVA is a relatively comfortable and robust programming language as compared to C/C++ or assembler.

While the device drivers have to be implemented by a software developer writing JAVA code, the control logic may be modelled using comfortable graphical tool software. This becomes possible because most of the control logic can be reduced to simple Boolean terms, i.e. $S_{Light} = S_{Switch}$ (to turn the light on as long as the switch is set to "on"). To control a light by three independent switches, a simple XOR logic can be used, like $S_{Light} = S_{Switch1} + S_{Switch2} + S_{Switch3}$. Figure 3 shows the DOMOLOGIC tool JControl/NetEdit, prepared to model the control logic of a domotic system. The tool automatically converts the graphic design into JAVA code, understood by the JAVA bytecode interpreter. In the same way as the lamp is switched, messages can be issued to the ASK-IT platform, for example, when the user opens the door and leaves his home.

Figure 4 shows a prototype of the ASK-IT specific user interface, easily operated by a touch panel. As a domotic system, it will support HS485 and Konnex/EIB networks for the proof-of-concept phase.

Figure 4 - ASK-IT Touch Screen Interface Prototype

2.5 Example

The following example illustrates the interplay between the ASK-IT platform and the domotic system. In this abstract setup, user John is on the move to another country. The relevant parts of the domotic system installed in his house are an automatic door lock, a door bell and a camera installed besides the front door. The door lock and door bell are HS485-compatible devices, connected to the LCU. The camera is an IP device, attached directly to the IP Backbone.

While away from home, John receives a message on his mobile phone that someone rang his door bell. He enters the "domotics" section of his ASK-IT user interface, running on his mobile phone, and checks the front door camera, giving him a picture of the person waiting in front of his door. He recognises his sister who told him before that she would come to his house to pick up some tableware she wanted to lend. Using the ASK-IT interface, John opens the front door remotely to let his sister in.

Altogether this example consists of three separate communication cycles: First, ringing the door bell provokes a message to John's mobile phone. Second, John requests an image produced by his front door camera. Third, he sends the command to open the door.

From a technical point of view, the following steps occur when John's sister rings the bell (see Figure 5):

1. The ringing of the door bell triggers a message on the HS485 bus.
2. The LCU generates a corresponding XML/SOAP event message, addressed to the Residential Gateway (RG), in order to contact the ASK-IT platform.
3. The Residential Gateway turns the message into a message compatible with the ASK-IT platform specification.
4. The ASK-IT platform sends a message to John's mobile phone.

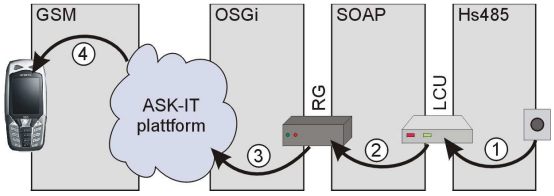

Figure 5 - Communication Flow 1

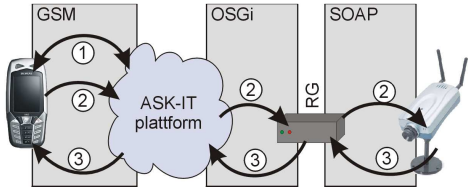

Figure 6 - Communication Flow 2

Requesting a snapshot from the front door camera works as follows (see Figure 6):

1. John establishes a connection to the ASK-IT platform over his mobile phone's web browser and selects the "domotics" menu. The ASK-IT platform displays a menu showing all the devices in his home.
2. John selects the camera from the available devices. The ASK-IT platform will now send a request via the Residential Gateway (RG) to the camera.
3. The snapshot is transmitted via the Residential Gateway and the ASK-IT platform to John's mobile phone.

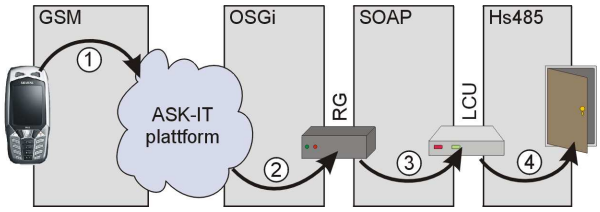

Figure 7 - Communication Flow 3

Finally, John wants to open the door for his sister (see Figure 7):

1. He returns to the main "domotics" menu of the ASK-IT web front end and selects the door and following the option "open".
2. The ASK-IT platform sends a request via the Residential Gateway (RG) to the door lock to open.
3. The Residential Gateway translates the request and passes it to the IP Backbone.
4. The LCU, receiving the request by the IP Backbone, interprets the message and turns it into an HS485 message to unlock the door by a HS485 message.

3 Conclusion

In this paper we outlined the synergy generated by the combination of ASK-IT and domotics. We propose a technical solution, taking its benefits of relying mainly on main stream components while being able to integrate existing domotic systems and devices. The control logic of the domotic system will be run distributed by embedded JAVA platforms, the *Local Control Units*. Drivers for specific devices can be implemented in JAVA; the logic behind the domotic system will be configurable by a graphical user interface.

By making the API and the protocol specifications available in the future, third party vendors will be able to implement their own drivers or logic components. The software components may be delivered with a device and uploaded to a Local Control Unit automatically.

On the long term, *ASK-IT enabled* devices or device groups can be developed and commercialised by third parties. This would simplify their integration into the ASK-IT platform, because the devices could be plugged into the network without any additional hardware or configuration.

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