

# Remote-Controlled Home Automation Systems with Different Network Technologies

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## Abstract

This paper describes an investigation into the potential for remote controlled operation of home automation systems. It considers problems with their implementation, discusses possible solutions through various network technologies and indicates how to optimize the use of such systems. The home is an eternal, heterogeneous, distributed computing environment (Greaves, 2002) which certainly requires a careful study before developing any suitable Home Automation System (HAS) that will accomplish its requirements. Nevertheless the latest attempts at introducing Home Automation Systems in actual homes for all kinds of users are starting to be successful thanks to the continuous standardization process that is lowering the prices and making devices more useful and easier to use for the end user. Even so several important issues are always to be handled strictly before developing and installing a Home Automation System; factors like security, reliability, usefulness, robustness and price are critical to determine if the final product will accomplish the expected requirements.

## Keywords

Home Automation Systems, Home network, Domotics, Ubiquitous access, User-friendly interfaces, Standards.

## 1. Introduction: Evolution of Home Automation Systems.

The concept of “automation” has existed for many years. It began with a student connecting two electric wires to the hands of an alarm clock in order to close a circuit of a battery and light bulb. Later, companies developed automated systems of their own to control alarms, sensors, actuators and video cameras and, in so doing, created the first automated buildings. The term “intelligent home” followed. Due to the obvious advantages of these systems, their influence on the conventional home was predictable and finally, in 1988, the term *domotics* was coined. “*Domotics is the application of computer and robot technologies to domestic appliances. It is a portmanteau word formed from domus (Latin, meaning house) and robotics*” (click on this link for more information <http://en.wikipedia.org/wiki/Domotics>). A modern definition of Domotics could be the interaction of technologies and services applied to different buildings with the purpose of increasing security, comfort, communications and energy savings (Moraes et al., 2000).

At the beginning automated devices were independent or, sometimes, grouped in small independent systems. But the idea of giving them interoperability using a common “language” keeps on growing up, consequently following such idea the first Home Automation Systems (HASs) appeared bringing a new concept of a home network full of possibilities, but this included also new factors to bear in mind.

In addition, a strong reason why of HASs are becoming popular is because they are plenty of attractive features that can easily lure companies to enter quickly this emerging market, also they represent a great research opportunity in creating new fields in engineering, architecture and computing (Huidobro and Millan, 2004). However, these new technologies are still in their early stages with a lack of robust standards creating compatibility issues affecting their

reliability. Another problem is that these systems are not always fully accepted by final users, especially the old and disabled – arguably the ones that need it the most. It is the goal of researchers to find out how to introduce home automation into our lives so as to only affect us positively. As an example, one effort to make these systems usable and affordable by any user helped the use of old, cheap and simple technologies like the X-10 protocol to transfer data in the home-network, in relative terms this approach created low cost HASs taking the advantage that X-10 technology do not require additional wiring. Even though newest technologies are constantly coming and a constant migration from wired to wireless is gradually affecting technologies involved within the home network possibly corroborating what Myers, Brad A. et al said that the future home network will have ubiquitous embedded computation with an increasing number of appliances having wireless communication (Myers et al., 2004). In fact, there are many recent tendencies to integrate various kinds of embedded devices and consumer appliances into software systems (Rigole et al., 2003), tendencies that have emerged from the ideas of pervasive computing. This evolution offers many useful possibilities in Domotics.

Lately, it is being proved that Domotics has many interesting fields, and among them using remote-Controlled HASs to control the home network is one of the most challenging. The possibility of having ubiquitous access to many devices within a building at any time, from anywhere, resolves many of the problems that users often face when they return home, saving a significant amount of time. It also notably increases the security in any kind of building and it may even provide a backup control system for local system breakdowns. This ubiquitous access could be achieved from many different digital devices and it is known that the network hierarchy has been rapidly moving lower in the chain towards smaller and more personal devices (Greaves, 2002). Considering latest tendencies, everything points at prompt remote control standardization in home networks.

## **2. Aims of the paper**

This paper has several aims:

- Show usefulness of remote-controlled HASs in Domotics
- Indicate the path evolution is following in Domotics
- Illustrate different ways to control of a home network using standardized technologies.
- Demonstrate the possibility of an ubiquitous access to the home network using actual technologies
- Explain possible actual benefits for Home Automation Systems
- Discuss several issues that may affect a remote-controlled HASs
- Propose a standardized remote-controlled HASs architecture
- Encourage (modular) user-friendly interfaces development
- To note down that the citation “provide an easier way to manage consistent user interaction in heterogeneous Environments” (Rigole et al., 2005) fits completely in Domotics

These aims have to be achieved thanks to an extensive literature review about Domotics and other related fields including network technologies such as 802.11, X-10, GSM, IP (using UPnP package) and several programming languages such as XML, WML, Java, C++ and .NET technologies. Additionally all contents in the paper must be backed by investigations

into the related social, ethical, legal issues and a meticulous investigation of the involved standards that may influence remote-controlled HAS in the actuality.

### **3. Why Remote Control?**

Wireless technologies represent a rapidly emerging area of growth and importance for providing ubiquitous access to the network; WLANs based on the IEEE 802.11 standard are being implemented constantly in the houses and Broadband wireless (BW) is also an emerging wireless technology which is competing with Digital Subscriber Line (DSL). According to this, it makes sense that the logical direction about managing HASs in the near future is going to be by means of a remote control. But wireless technologies in domotics should be implemented carefully.

This paper aims to answer the following questions :

- What are the benefits of using remote control in domotics?
- What are the main issues of using remote control in domotics?
- After studying issues and benefits of remote controlling, is it still profitable to use remote controlled HASs?

#### **3.1. Home network remote-controlling benefits**

The increasing ubiquity of heterogeneous computing devices such as laptop computers, palms, mobiles etc. shows that users prefer a ubiquitous access of a system rather than to be uncomfortably forced to go physically to the nearest control point. Remote control saves time and everybody is aware of this, it also provides increased security and flexibility. For example, if the user receives a SMS saying that there was an intrusion, he/she can connect to the internet and watch the video cameras inside the house to see what happens, another example could be the possibility to turn on the heaters from the distance using a mobile, laptop or PDA so as soon as the user reaches the house it will be hot already, this could be really useful especially in cold countries. As a matter of fact security will always be a main priority in all families, and prevention is better than cure. By receiving alerts in a portable device user is informed of all possible issues occurring in the house and it gives the possibility to deal with it using different ways of control like instant messaging, since many users are already familiar with the concepts and user interfaces of instant messaging. Many computers and mobile devices also already have instant messaging clients installed (Aurell, 2005).

Good scalability properties, independence of location or geographical distance, and high flexibility due to the different existing protocols make remote-controlling HASs suitable for most user needs.

#### **3.2. Home network remote-controlling issues**

Roychowdhury and Moyer (2001) identify four primary reasons:

1. Interoperability
2. Scalability
3. Security
4. limited services

Interoperability refers to the capability of devices of different types and from different manufacturers to communicate and cooperate. Scalability refers primarily to scalability in terms of geographical distance and location independence. In the context of offering remote access as a service, scalability in terms of capacity would also be an issue. Security is probably the most important issue among them and the hardest to deal with regarding the media used in wireless communications. Finally, Limited Services due to bandwidth limitations of wireless networks in comparison with other wired technologies.

In addition to Roychowdhury and Moyer (2001) reasons, two more important issues have to be mentioned:

5. Usability
6. Existence of multiple standards

HASs are not being well accepted by old or disabled users and, in some cases, users don't like computers controlling their lives. While appliances get more computerized with more features, their user interfaces get harder to use forcing users to come back to the old behaviour with their appliances again (Nichols et al, 2001), this lack of acceptance is worse when users have to use complex hand-held/portable devices or small interfaces. And the existence of multiple standards is a major obstacle for deployment of wireless networks, while GSM is the only widely supported standard in Europe and Asia for mobile communications, multiple standards are in use in the U.S.

### **3.3. After considering benefits and issues**

Even with all issues related to remote-controlled HASs it seems that the benefits are just good enough to continue advancing in this field, also just recently, organizations have been formed to ensure network and device interoperability. For example, the adoption of the 802.11b standard has made wireless data networks one of the hottest newcomers in the current wireless market. As a result, in one hand remote-controlled HASs represent in Domotics a great opportunity to improve human computer interaction thanks to its ubiquitous access, but in the other hand they represent one of the most challenging environments due to involved security issues and relative complexity of portable devices.

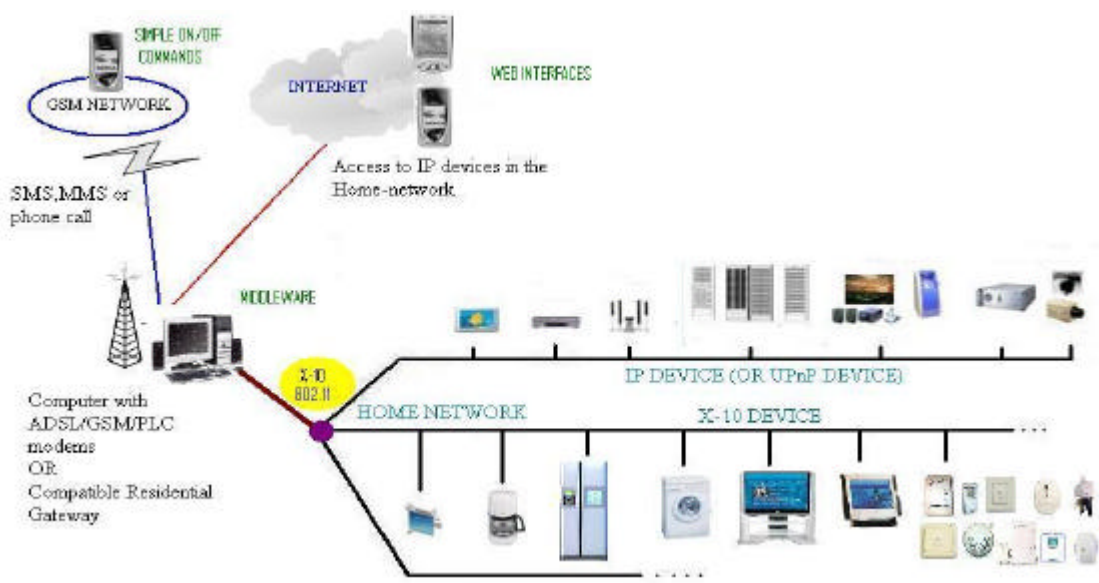
## **4. Architecture of the Remote-Controlled HAS**

It is clearly necessary to have an organized and defined structure for HASs (Cortes, 2002). Since their creation normally involves different areas of electronics, architecture and computing, there are many different ways to develop solutions and not all of them can be applied to all users. This makes them difficult to implement due to the high impact that they might have on the everyday user. Using an overall view, a Domotics project can be divided into three stages: *Study*, *Definition* and *Installation*. In the study section, it is very important to know which benefits the users are going to get with the project and which technologies are going to be used. An optimal study will help considerably at the definition stage where inputs, outputs and processes are more defined. The last two steps can be completed with the help of software tools, although not all HASs have to follow this model. A well defined domotics model is the one used in the project Amigo (Kalaoja, 2006), this project is based in a semantic modelling of services that enables interoperability of heterogeneous services. The

ontology may facilitate clear description on how far each device is suitable for different kinds of information and different interaction demand.

Another important approach more oriented to the concept of the home network, and one of the most widespread, is to divide the whole network into three: *Data*, *Control* and *Multimedia*, making it easier to manage the whole system - optimizing technology applications and allocating them in different areas of the network with better purpose. In a remote controlled HAS the home-network will be approached differently depending on the selected protocol for the service and the required bandwidth. For example, control via a mobile using the SMS service can be achieved using the X-10 protocol, but advanced control of video cameras or appliances requiring video or heavy interfaces will fit better if it is used the Internet via TCP/IP and a web server. There are many ways of approaching a HAS but, if the final product contains a bad-structured network, it will make the project less secure, less useful and it could fail in its scalability.

Candidate technology to standardize the remote-Controlled HASs is the Internet Protocol (IP), using UPnP package which is totally compatible with strongly standardized technologies such as IP, XML, HTML and WML; while the X-10 which includes RF (radio frequency) compatible devices that enables the use of remote controls inside the house, and the GSM (Global System for Mobile Communications) Digital standard provide an outstanding backup emergency control. Remote access will be achieved outside the building from the Internet and GSM networks and inside the building through the home network using the 802.11 standard and the X-10 protocol. Among other factors that will affect the final performance of the remote-controlled HAS we have the decision to select the programming language/s. Normally any programming language should be suitable to create the interfaces and to link the home-network with the outer networks but, when linking certain technologies and standards, some languages are more reliable than others, depending on their portability and library provision. Also other factors such as the global linking of the system or the usability and scalability of the final product will have to be considered at the time of the final binding. The summarized schema of the HAS is shown below:



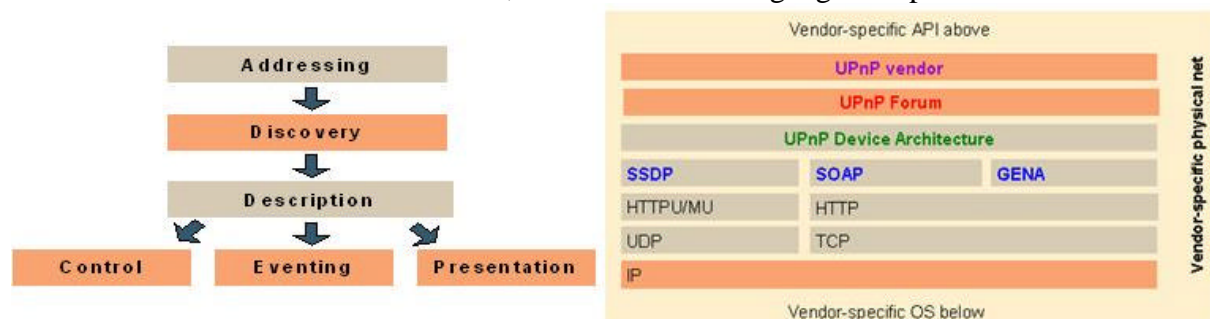
**Figure 1. Remote-controlled HAS**

In accordance with the objectives defined, the final system must achieve remote control, with practical interfaces involving different technologies and the different devices compatible with

the selected network protocols. A useful and scalable remote-controlled HAS is produced and its functionality tested using UPnP or X-10 compatible devices. Encouraging remote control, comparing actual standards and accelerating the process of standardisation in HASs are also important factors to consider and it is necessary to use low-price materials in order to make cheap HASs commercially available, sooner, for everyone. The whole control cycle must be complete from the user selecting a control action from their remote point until the target device realizes the desired action.

#### 4.1. IP Remote control

UPnP (<http://www.plug-n-play-technologies.com/>) is a lightweight architecture to extend the Plug & Play concepts to network devices and services UPnP defines two roles of devices: control points who act as clients and controlled devices who act as servers. It is very flexible and it comes with several helpful solutions for a Home-network. Controlled devices are containers which embed services and other controlled devices Services define the functionality offered by the device and control points use the services to control the device and monitor their status. The architecture do not defines an API, and is therefore language independent.



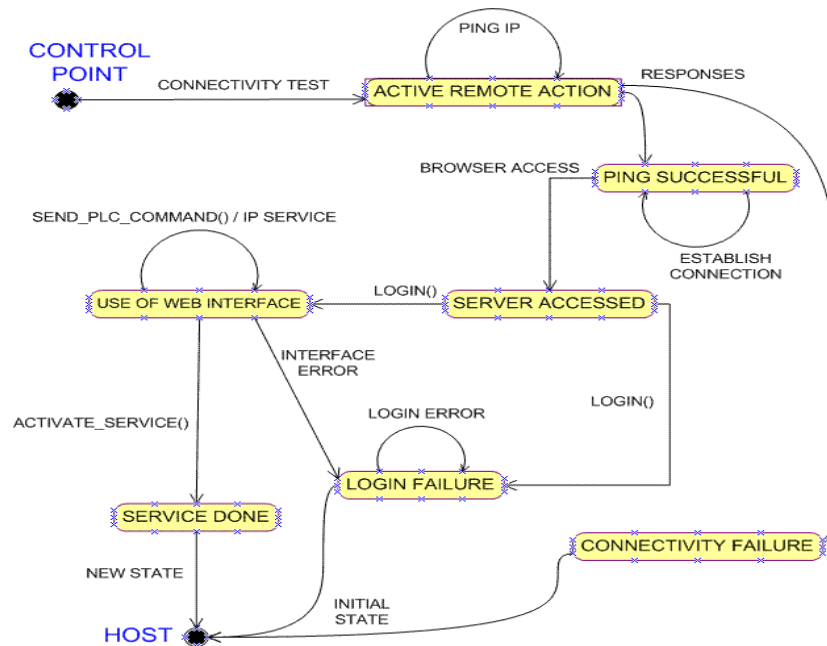
**Figure 2. UPnP stack and stages**

A brief definition of the different stages:

1. **Addressing** ensures that each device receives a valid IP-Address
2. In the **Discovery** stage defines how control points can find controlled devices.
3. During **Description** a control points receives the device and service descriptions (expressed in XML) of the controlled device. The device descriptions contain several standards and vendor specific device information and a list of embedded services and devices. The service description contains the actions and state variables of the service.
4. The **Control** stage uses SOAP (Simple Object Access Protocol) to invoke actions of services. SOAP is a RPC technique that uses HTTP as the transport protocol and XML for marshalling.
5. At the **Eventing** stage uses GENA (General Event Notification Architecture) to inform control points of state changes occurred at controlled devices.
6. A **presentation** page can be presented for user control. This step delivers a HTML (or WML) page to the control point. Better defined or specific interfaces could be required for special users perhaps even using flash.

UPnP package is directly connected to the Device and Service Descriptions defined by the UPnP Device Architecture. The descriptions are expressed in XML. The object model can be generated from a corresponding XML-File. Also the XML representation can be accessed by the object model. UPnP comes with a well defined and structured hierarchy of classes that makes implementation highly reliable.

IP remote control cycle is as follows:



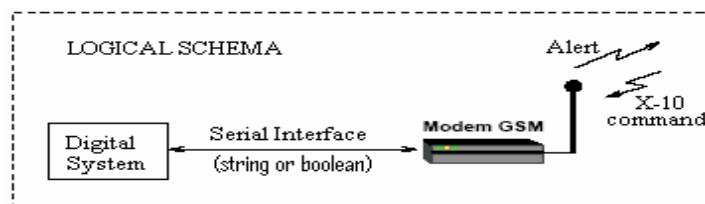
**Figure 3. IP device remote control**

The diagram represents the different states of the HAS since the web server is accessed until the service is processed or not by the host. Web server has to be login-session enabled.

#### 4.2. Backup GSM Remote Control

The Global System for Mobile Communications (GSM) is a digital standard wireless technology GSM is the most widely used wireless technology in the world with one billion customers globally, which represents 72% of all wireless customers. GSM has a high presence among users (almost everybody has a mobile) raising the probability of the remote-controlled HAS to be accessible, furthermore by programming the GSM modem using AT/AT+ commands it provides another security layer (modem will respond only to specific mobiles) and certain robustness. At this backup level, the interaction with the user is very simple; the bilateral communication is reduced to the minimum, only representing emergency processes. Eventually, the remote-controlled HAS will send alerts to the user's mobile informing about unusual state changes in the sensors within the building, afterwards user is able to activate/deactivate some automated devices required to solve the issue either by dials or messaging or, in the usual case, using a web interface, in any case the user will have always two possible accesses in case that one fails. Normally the probability of accessing the GSM network will be higher than accessing the Internet.

The schema of the system is as follows:



**Figure 4. Logical schema for GSM control**

The simplicity of the X10 command "<X10 address>", "<RF command>", "<keydata>", "<timestamp>" (All parameters are specified as string values), permits to encode the command as a string, and eventually some Booleans might be used to manage the state of the modem.

It is important to mention that the use of a friendly-user interface is extremely relevant in an emergency backup control, to achieve it, exists the possibility to use templates already defined in the mobile to send messages, and simple and visible ON/OFF selections to establish different dialling.

Backup control cycle is as follows:

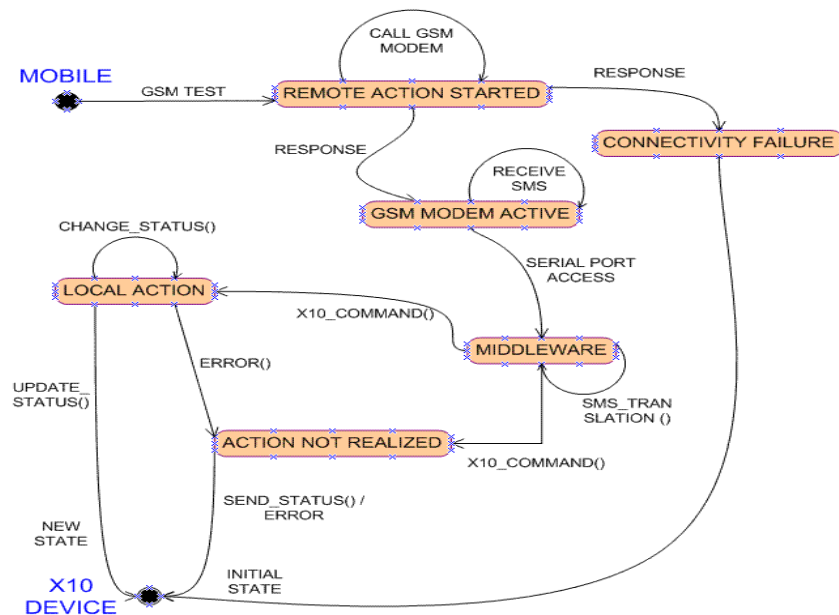


Figure 5. GSM Backup Control

### 4.3. User-friendly Interfaces

Nielsen, Jacob and Rolf Molich (1990) said that there are basically four ways to evaluate a user interface: Formally by some analysis technique, automatically by a computerized procedure, empirically by experiments with test users, and heuristically by simply looking at the interface and passing judgement according to one's own opinion. In Domotics, the most suitable could be the empirical one, analyzing heuristically an interface can give an idea of the potential usability that it might have but since, in a home network, users may have any portfolio the best way of assuring the usability of the interface is experimenting with the user directly.

Some of the most extensive evaluation effort has been focused on determining exactly what users might want, using techniques such as surveys and interviews (Mankoff et al., 2003). Additionally, researchers investigating displays that combine ambient awareness with notification, or alarms, have conducted some formative analysis (Chewar and McCrickard, 2002, and van Dantzich, 2002). In particular, Chewar and McCrickard (2002) have discussed work in progress on modifying a formative in-use study methodology to apply to notification displays (Mankoff et al., 2003).

Undoubtedly the solution proposed by P. Rigole et al. (2005), seems to adjust closely to different specific user requirements by means of an indirect exposure of a component's

interfacing needs through Interaction Components (ICs). This way, interfacing needs can be described in an abstract way at the level of a component, and transformed into concrete interfacing widgets at runtime by the ICs. In addition, this approach also tackles the problem of runtime user interface mobility between devices offering heterogeneous interfacing capabilities. During a relocation of software components from one host to another, the concrete user interface is regenerated using the abstract interface representation and the limitations of the new host. (Rigole et al., 2005) The point is to build a modular interface flexible enough to adapt to all users in order to fit user's individual preferences or needs. The user will be able to have larger buttons that are easier to press or fewer options to make the interface less cluttered. For disabled users, the HAS could generate an interface with suitable properties for that disability, such as a Braille interface for a blind person or an interface with only a few buttons for someone with a cognitive impairment (Myers et al., 2004).

To finalize, interfaces have to achieve another important feature: reusability; different devices in the home may operate similarly executing comparable processes that can be almost equally developed in the HAS, this saves a significant amount of time and makes the system more stable.

## 5. Conclusions and Future Work

The process of standardization in Domotics is becoming the most important factor to introduce an automated environment in all homes. There are already E-home standards settling up in Europe, the example is the European Installation Bus (EIB) that is the world's leading system for "intelligent" electrical installation networking (<http://www.konnex.org/>). Not to forget That UPnP providing total compatibility with XML and IP. I agree with Simon Aurell (2005) that the most likely way of interfacing with devices in the future will be IP; it is more flexible, scalable and compatible. The biggest issue will be probably to make it usable and accessible to all kinds of users.

Since this is a new field of investigation, the results of the project are likely to be worthy of further analysis. The completion of a whole cycle of control between a remote device and the building will be critical for the success of the research; once control is achieved a meticulous study about how users and the system interact has to be done. It is important to clarify that this research does not exclude local control of HASs - it is simply focused on remote control as an important field for HASs in the future. To conclude, this research should help other researchers to achieve their goals with their future HAS projects and it will contribute positively to the E-Home community.

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