IoT Household Controlled by Cloud Technology

PETER PAPCUN, IVETA ZOLOTOVÁ
Department of Cybernetics and Artificial Intelligence
Faculty of Electrical Engineering and Informatics
Technical University of Košice
Letná 9, 042 00 Košice
SLOVAK REPUBLIC
peter.papcun@tuke.sk
iveta.zolotova@tuke.sk

Abstract: - Contribution describes research and development of economic, comfortable, intelligent and smart premises for households, offices, workplaces and others residential or business premises. This article describes realization of intelligent household's scale model, which uses the newest technology for smart and comfortable living. Today's smart products are using local control, which are controlled by remote controllers or applications in smart phones and tablets. So people who bought these things have more and more controllers. Mostly, these products do not communicate between each other, so user controls every product separately. Therefore, we used mainly remote control using cloud systems and cloud computing in this research and development. We use the Internet of Things (IoT) solution to connect products in the house to the Internet, so we designed products (things) in house connectable to internet only with home WiFi router, which have every average household.

Key-Words: - IoT, Cloud, household, control, tablet, smart phone, web-page, Smart Living, Smart House

1 Introduction

Nowadays more and more devices are connecting to the Internet. These devices are not only computers, smart phones, tablets and televisions but these are fridges, washing machines, or coffee makers. White goods producer has taken IoT concept to their production. In the past, it was a necessity in the industry connects each sensors and actuators to technologic networks, because productions lines have to be controlled by control units, which are connected to this network. Today is effort connects to global network everything, even dust (Smart Dust). This is world of IoT.

White goods are part of household. These goods have to be controlled. If you buy IoT goods, you want services from these goods. The best place for services, control and manage is a cloud. Producers has own clouds solutions on their servers (private cloud). We use public cloud in our solution specifically Microsoft Azure. When customer want use own private cloud, this cloud has to be in customer household (for example Raspberry Pi with minimal energy consumption).

In today's times, people have possibilities buying intelligent products (Smart Home, Smart Living) to household as intelligent bulbs, switches, sockets, and many other products. These products are on the market through previous research, which was running last years. Products use local control via remote controller or smart phone. Count of these controllers raise in household of people, which buy intelligent products (remote controllers, applications in smart phones, tablets, etc.). Mostly these controllers do not communicate between each other, so user control every type of products separately.

2 Internet of Things and Cloud

According to studies, it is expected that under the next ten years, the average household will have 50 things (products) connected to internet. This expectation is followed with increasing number of nodes connected to internet. In 2010, 12.5 billions ($12.5 x 10^9$) devices were connected to internet and this number continues to grow. It is not except that this trend will stop. We want to contribute to the development of these products (things) connected to internet.

Trend to the future is Internet of Things (IoT). The aim of IoT is connect to global network internet as many things (products) as it is possible. We want to develop household with many elements connected to internet through remote control on cloud system. Certain parts of mentioned research and development are described in this article.

Cloud technology and IoT belong to the foremost research and development in IT area in world. Computing power of servers and cloud systems continues to grow and services prices are decreasing. Cloud system (cloud computing) is future.

One of our aims is that people have not to buy smart technologies with computing and control units. Smart device will be able to connect to home network and cloud will take care of the control. We use the latest features of cloud systems for this remote control. Specifically, we use cloud possibilities from company Microsoft (Microsoft Azure).

3 Model of Household

On our laboratory we are working on IoT household controlled by cloud systems. We are building a scale model of household. Design of ground plan is on figure Fig.1:

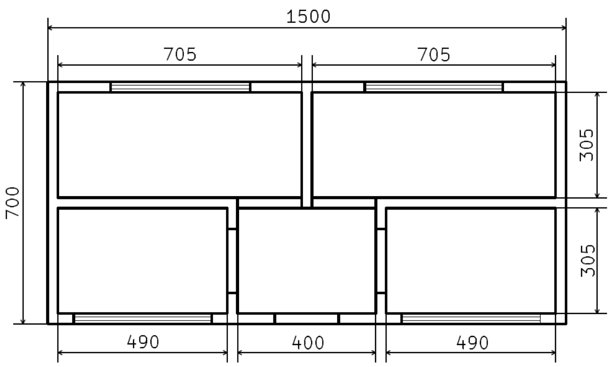

Fig.1 Ground plan of model (units in mm)

This model is built from extruded polystyrene, roof and windows are from plexiglass, doors are wooden and floor is from laminate. When we implement all cables, sensors and actuators to polystyrene and laminate, model will be plastered with whole technological process (cement construction mortar, fiberglass mesh, plaster). Basic frame of model made of polystyrene is on figure Fig.2.

IoT products will be installed to this model. These products will be connected to cloud Microsoft Azure. Products control will run on this cloud as a service. If all components are connected to one platform, then they have the chance and the ability to communicate between each other, this communication is absenting at today's smart products mostly. Communication between things and products brings new possibilities for comfortable living. For example, coffeemaker does not turn on at a certain preset time, but when user parks his car, eventually user comes home.

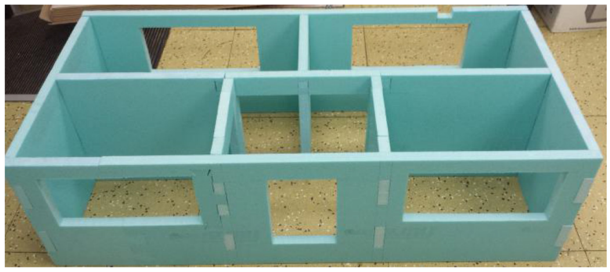

Fig.2 Basic frame of intelligent household model

During the design of IoT products will be emphasis on easy installation and the capacity of the network in the household. In average household, home router can connect 254 nodes (elements, products, things) by wireless network WiFi and by Ethernet cable. Nowadays, home routers use IPv4 addressing with 24 bits of network prefix for own private network, therefore is the limitation to 254 nodes. In future, IPv6 addressing will be very important for IoT world.

In addition to this, we will heed to healthcare through intelligent house. Healthcare will be ensured by controlling the atmosphere in the rooms or follow users' behavior in apartment by a camera system and microphones (fall, scream, etc.) and based on the inputs to the system call for help. Of course in house will be a large number of sensors and actuators, which will be specified to other activity, but they will be able to participate in healthcare.

After successful completion of the model, the created model can be used in education of IoT Systems, Cloud Solutions, Architecture of Industrial Information Systems, Single-chip Microcomputer, Computer Systems in Control and other studies courses dealing with the latest technology.

Already in the past in our department, we were conducted research and development of intelligent and energy-efficient living spaces (household, office, etc.). It was a local control of house model with visualization. Research and development of this model is described in [1], [2]. In addition, this model was used in the process of education and teaching. Therefore is the large assumption, that the new model will be used also for these purposes. Mentioned model has worked on other technologies than the new model, which we are describing on this contribution.

Research, development and build of this new model of household are a project. We named this project. Its name is CASTLE (**C**omfortable **a**nd **S**mar**t** **L**iving **E**xpanded).

4 Phases of the Project

This project is divided to four phases. The first phase designs and models house with necessary electrical installation. The second phase builds the model of house with electrical installation. The third phase realizes temperature and light control by cloud technology from Microsoft Azure. The last phase realizes control of other elements by cloud system (for example RFID, camera system, etc.).

4.1 The First Phase

This phase designs the used building materials, cabling, basic installed elements, ground plan, wiring project for model of house. Besides, the first phase creates simulation model for physical model of household.

The first phase is completed. Building materials are extruded polystyrene, plexiglass, wood, laminate, cement construction mortar, fiberglass mesh and plaster. The use of the mentioned materials is described above. Model of house uses 12 V and 24 V DC electrical installations, because we use actuators and sensors with mentioned voltage. Also 220 V AC is dangerous for scale model of house. Basic installed elements are intended for thermal and light systems (temperature sensors, peltiers, blinds with drive, LEDs, etc.). Ground plan is on figure Fig.1.

Simulation model is programmed in program language C# through environment Unity. We can simulate thermal system, thanks simulation model of household. Algorithm of temperature control is programmed and simulated here. Simulation model includes thermal throughput of polystyrene, wood and plexiglass. We use fuzzy regulation for temperature control.

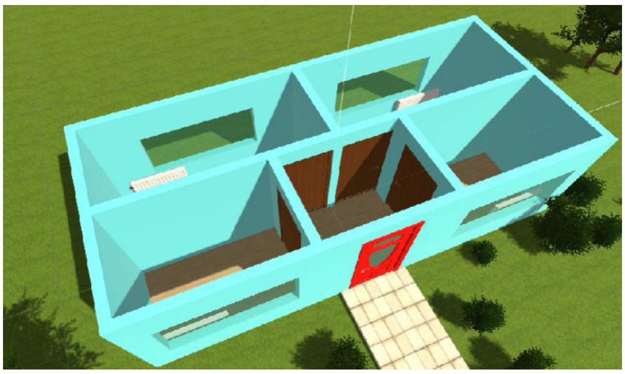

Fig.3 Simulation model of household

This simulation model can be use also for layout design of sensors and actuators. Simulation model of household in Unity is on figure Fig.3.

4.2 The Second Phase

During the second phase is built the model of household. The procedure is described in the description of the model. Basic frame of intelligent household model is on figure Fig. 2. Laminate flooring is elevated from the bottom to add more sensors and actuators.

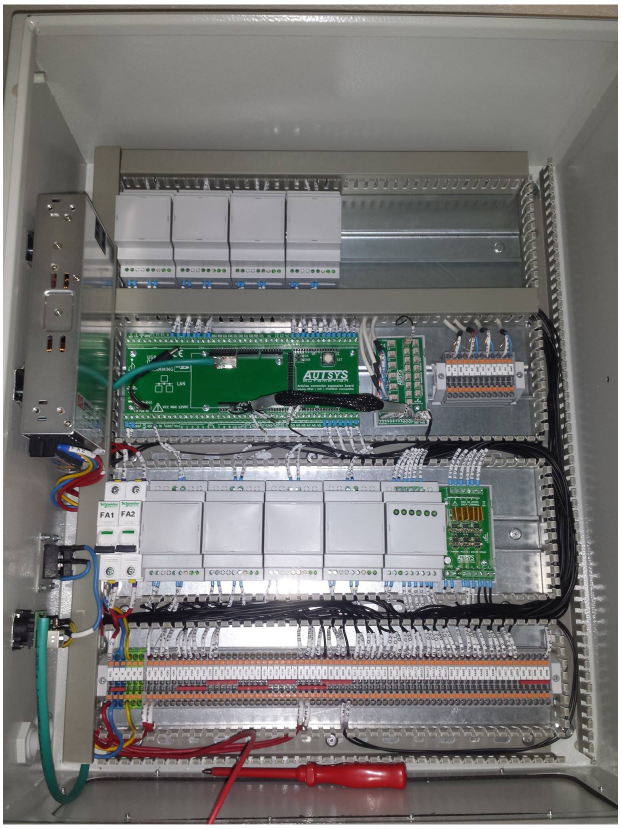

Fig.4 Switchboard

Realization of switchboard is included to this phase. Switchboard for our model is on figure Fig.4.

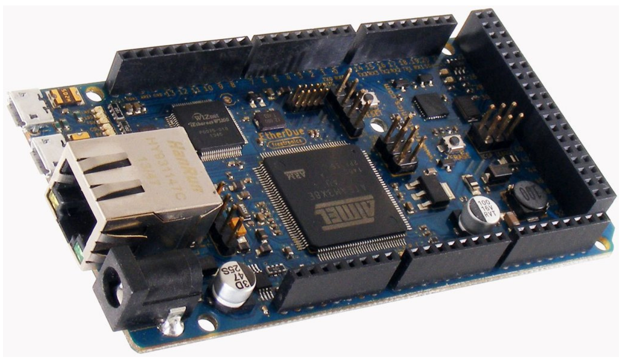

Fig.5 EtherDue

Control unit of switchboard is EtherDue, its place is on socket where you can see Ethernet and power cable (the second row of electrical elements on figure Fig.4). EtherDue (Fig.5) is device with same architecture as Arduino Due with Ethernet shield, but EtherDue has integrated Ethernet interface.

4.3 The Third Phase

When we have constructed the model with switchboard and we have simulated thermal system, we can program this control to cloud system. This control is programmed as a service through Microsoft Azure. Using the same service is also controlled lighting system. This service will be enriched by control of IoT products developed in fourth phase.

4.4 The Fourth Phase

At this phase will be designed other IoT products, which will use in project. Priority will be to search existing IoT components for household, but their number is still low, so this design will be extended.

The extended part of design will propose equipments individually from appearance design, via electronic proposal, to material design. Finally, all proposals will be implemented and installed into the model of household. These equipments will be connected to cloud from Microsoft Azure. Communication protocols will be set and programmed. Regulation and control will be programmed for designed IoT equipments (products, things). Creating a web HMI (human - machine interface) environment for the user will be also necessary (in addition to the necessary services for control). This webpage (HMI) will be part of the cloud system creation. For a long time, HMI is not just a matter of industry. Search, design and programming of possible interactions between elements in the home will be part of this phase. At this phase we are still working. Many sensor and actuators make possibilities for multi-agent systems with interactions.

5 Models of Control

The first idea was to keep the whole control of house on the cloud. This model of control works, but household becomes dependent on internet connection. If the provider can guarantee non-stop connection to the internet, then control can stay on the cloud system.

In 1961, John McCarthy defines utility computing and he compares this utility computing with electricity and water. His idea was that in the future we will buy computing power as electricity or water in the home. [3]

With this mentality and after few years, people can be dependent on the remote cloud-based systems and the internet than now on electricity and water. So we decided not to leave everything to the remote and public cloud and we come with three options:

- control and HMI through public cloud,
- control and HMI through private cloud,
- control and HMI through hybrid cloud.

Previously, often was mentioned service for control in this paper. These services can be named CaaS (Control as a Service). Classically, cloud services are divided to:

- IaaS (Infrastructure as a service),
- PaaS (Platform as a service),
- SaaS (Software as a service).

CaaS is software service, which is specialized for control. CaaS is not defined as a basic group of cloud services, yet. We are not the first, who use term CaaS, before us use this term [4], [5].

5.1 Control and HMI through Public Cloud

We use services from Microsoft Azure for control and HMI through public cloud. Microsoft Azure has special services for IoT products. These services are IoT Hub, Event Hubs, Stream Analitics, etc. There are other companies offering similar services, for example IBM with IBM Bluemix, Amazon with Amazon Web Services.

This time, we have implemented two types of architecture and we are working on the third architecture:

- Raspbery Pi as IoT gateway with operating system Windows 10 IoT core,
- EtherDue communicates by HTML requests with cloud system,
- EtherDue communicates by MQTT or AMQP with cloud system.

The first architecture was presented at Microsoft IoT Hackathon by our research group. The second architecture is using on our household model.

In this solution, webpage (HMI) and control algorithms are running on the public and remote cloud system. All information from sensors is sending to cloud and all information to actuators is receiving from cloud. This solution is dependant on internet connectivity fully.

In this case, the provider of cloud services is responsible for security. Safety is in the hands of an integrator (or user) that installs IoT products, programs control and HMI webpage for household.

5.2 Control and HMI through Private Cloud

User (or integrator) can build own server, which will control user's household. If user uses classical server or personal computer, then house is not economical, because classical computer has average power consumption 200 W (from 70 W to 500 W), that is mean 1700 kWh per year. If user uses notebook as a server, then average power consumption is 50 W that is mean 425 kWh per year. But when is used Raspberry Pi (Fig.6), then power consumption fall to 2 W that is mean 18 kWh per year.

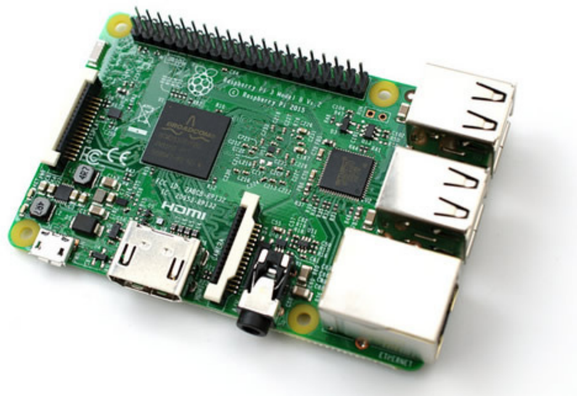

Fig.6 Raspberry Pi model 3

When we want use the home server, we need public and fixed IP address. Most internet providers use dynamic or private IP address, because they want provide internet to many people with small address space. If we use private address, then control will function only in local home network and user can not control house by HMI outside of this network. If we use dynamic address, then we have to know our actual address every time, when we want connect to our house.

If we have fixed and public IP address, we can implement our solution of control by private cloud. Control algorithms and HMI webpage is programmed on Raspberry Pi and every IoT product has to communicate with Raspberry Pi.

Security and safety are in charge integrator in this case.

5.3 Control and HMI through Hybrid Cloud

This model has distributed control algorithms and HMI webpage. Control algorithms are running on private cloud and HMI is running on public cloud. Fixed and public IP address is not important, because communication between clouds provides HTML requests. Private cloud is a HTML client, which is sending requests to HTML server (public cloud) every sample time.

Controller (private cloud) may not be the computer, but controller can be Arduino with Ethernet or WiFi shield, EtherDue or any single-chip microcontroller with Ethernet or WiFi. HMI webpage is running on public cloud and user can monitor and set household from everywhere, because these clouds communicate between each other.

6 Research and development impacts

Thanks to this project occurs development in two directions immediately: the development of IoT products and the development of CaaS for households. The web server is running on the cloud, thanks to this web can be controlled and set requirements of household. So the user can control the particular thing at home on a tablet, laptop, smart phone or other device which can displays the webpage. Such control would not be necessary to develop separately for each households, it could develop only one service that could be joint to any household.

Mentioned process would reduce the cost of production of these smart devices and the development of control would not be directed to a specific household. A control algorithm could be used for any household.

6.1 Benefits

Results can be divided into three groups:

1. technical or hardware solution,
2. software solution,
3. methodic.

The technical solution includes a functional model of a smart home with all installed IoT elements connected to the global internet. This smart home with IoT elements will be controlled from a web browser and its will be regulated and controlled remotely. The technical solution will also include various IoT elements, which will be developed under the project CASTLE. Until that time, it was developed:

- thermo-regulatory elements made of peltier, heatsink and fan,
- system of temperature sensors,
- light system: system of actuators (blinds, LED lights) and sensors (photoresistors),
- switchboard.

Software solution includes:

- individual firmware for IoT products,
- remote control and regulation algorithms for IoT products,
- web HMI environment running on the same platform as control and regulation of IoT products,
- algorithms of interaction between IoT products.

Methodic was mentioned in chapter *Models of Control*, where was described control and HMI through private, public and hybrid clouds.

7 Conclusion

The project will benefit in the social sphere, whether it will be a comfortable living, intuitive systems or price reductions of smart products. This product will benefit the production sphere, since in this area may find inspiration. Also, platform of application developed during this project foresees significant potential for commercial use.

Project CASTLE (model and concept of system creation) has a high envisages the use in education of the latest technology. Specifically, the education of IoT Systems, Cloud Solutions, Architecture of Industrial Information Systems, Single-chip Microcomputer, Computer Systems in Control and other studies courses dealing with the latest IoT and cloud technology.

After the successful implementation of the project CASTLE, our team wants to continue creating smart IoT rooms (laboratories) at our department. We want move from a physical model solution to a real solution. In future, this solution can be used in real households, offices, workplaces and others residential or business premises.

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