IoT and Cloud Technology as Ubiquitous Computing in Case Study of Intelligent Household

PETER PAPCUN, ERIK KAJÁTI, IVETA ZOLOTOVÁ

Abstract: - Interest in Smart Homes is growing and this trend will not change in the coming years. More and more companies offer their own smart solutions. With this rising trend, there is also bigger need for the Internet of Things (IoT) devices that can communicate with each other, can be controlled remotely and that can provide added value to standard home appliance devices. Users want to know what is happening at their homes when they are away, they want to maintain control of their households at every time. This article describes some of the solutions that can be applied to the households and describe the building of the model house to test these solutions and to apply developed IoT devices. Moreover, there are described and tested different types of cloud services based on the location of the cloud servers. Our main aim was to create educational and research model for developing new network and control architecture via modern technology with IoT concept. Various control and communication architectures will be implemented using this model. We also describe some future plans and proposals for new ways of how to use and implement IoT devices.

Key-Words: - IoT, Cloud, HMI, M2P, remote control, Smart Home, Control as a Service, Arduino

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I INTRODUCTION

Nowadays more and more devices are connecting to the Internet. These devices are not only computers, smartphones, tablets, and televisions but also 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 to connect each sensor and actuator to technologic networks, because productions lines have to be controlled by control units, which are connected to this network. Today effort is to connect everything to a global network, even a dust-sized devices (Smart Dust). This is the world of IoT.

White goods are part of the 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 management is a cloud. Producers have their own clouds solutions on their servers (private cloud). We use public cloud in our solution, specifically Microsoft Azure. When a customer wants to use an own private cloud, this cloud has to be in a customer household (for example Raspberry Pi with minimal energy consumption).

In today’s times, people have many possibilities to buy an intelligent product (Smart Home, Smart Living) to the household like intelligent bulbs, switches, power outlets and many other products. These products are on the market through previous research, which was running in the last years. Products use local control via the remote controller or the smartphone. The quantity of these controllers raises in the household of people, which buying intelligent products (remote controllers, applications in smartphones, tablets, etc.). Mostly, these controllers do not communicate with each other, so user controls every type of product separately.

The idea of IoT is interconnectivity. Not only people will be able to communicate with IoT products, but IoT products will be able to communicate with each other. People will be supervisors of their IoT products and households via web applications with their smartphones, tablets or computers.

Our solution used mainly remote control using cloud systems and cloud computing in this research and development. IoT products can communicate with each other. Local control is not necessary, the product can be controlled by cloud technology and users do not need the local controller. We use the IoT solution to connect products in the house to the Internet. So, we designed products (things) for the house that can connect to the Internet by only using the home WiFi router, which has every average household.

One of the frameworks for cloud-based smart home was defined by [23] with three main layers: an infrastructure layer, a platform layer, and a service layer. Our solution built all these layers for three different cloud architectures (private, public, and hybrid) described in [24]. Layers from [23] in our solution:

- infrastructure layer: scale household model with sensors, actuators, and controllers,
- platform layer: Windows 10 IoT core or program in Arduino,
- service layer: Services for household control.

Many research groups ([25], [26], …) are solving IoT gateways for communication with cloud systems. These gateways are very important for this solution. Our research group is also solving this problem, this can be seen in [6], [7], and [22].

IoT products with an own controller or with the cloud control make ubiquitous computing. These IoT products have to be indexed [16], this indexing is also necessary for our solution.

II INTERNET OF THINGS AND CLOUD

According to studies, it is expected that in the next four years, the average household will have 50 things (products) connected to the Internet. This expectation is followed with increasing number of nodes connected to the Internet. In 2010, 12.5 billion (12.5×10^9) devices were connected to the Internet and this number continues to grow (according to [14], [21]). It is not expected that this trend will stop.

Nowadays, average family (household in Europe and North America) has two laptops, one computer, two televisions, two set-top boxes, three smartphones, and two tablets connected to the Internet. That is 12 IoT products. Approximately 9 devices were connected to the Internet in UK household in 2015 according to [15]. In next three years, people will change their white goods for IoT white goods, because the price of these goods will be same as classical goods today. Average European household will have more than 50 IoT products, by 2020. People will connect to the Internet other things as thermostats, boilers, lights, conference tables, kitchen countertops, power outlets, etc.

According to our assumption, this number will overcome the study mentioned in [15]. We want to contribute to the development of these products (things) connected to the Internet.

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

IoT is a network of physical objects (things) connected to the Internet. These physical objects have to consist of the controller with communication module and software. Nowadays, people have 12 IoT products at home, in next few years, it will be 50 products. Every of this product has a controller unit, that means computing will be ubiquitous. But we see ubiquitous computing in an even wider sense of interconnectivity, this is described below. IoT world is the way for ubiquitous computing. Interesting opinion is described in [17].

Cloud technology and IoT (Fig.1) belong to the foremost research and development in IT area in the world. The Computing power of servers and cloud systems continues to grow and price of the services are decreasing. Cloud system (cloud computing) is future.

Fig. 1 IoT products connected to cloud [12]

One of our aims is that people should not buy smart devices 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).

Cloud providers offer services for IoT products connectivity, web applications, mobile applications, databases, real-time running applications, etc. All of these services will be useful for our solution:

- IoT products connectivity for device interconnection,
- the web and mobile applications for an interface between users and IoT products,
- databases to store information,
- real time running applications for household control.

We are at the beginning of a new technological revolution: an era where thousands of hitherto disparate and unrelated devices will become connected and able to share information via cloud-based services. This type of interaction will ultimately be made possible through hundreds and thousands of connected sensors, actuators and monitoring devices attached to physical objects, or otherwise embedded into the fabric of buildings, or simply dispersed within the ambient environment. [12]

Inputs and outputs of mentioned sensors and actuators will make large amounts of data, what is opening options for Big Data and Data Mining.

III MODEL OF HOUSEHOLD

In our laboratory, we are working on IoT household model controlled by cloud systems. We have built a scaled model of the household.

The frame of the model is built from extruded polystyrene, roof and windows are from plexiglass, doors are wooden, and a floor is made of laminate. When have implemented cables, sensors, and actuators to polystyrene and laminate. The model is plastered with a whole technological process (cement construction mortar, fiberglass mesh, plaster). The basic frame of the model made of polystyrene is in figure Fig.2.

IoT products are also already installed on this model. These products are connected to Microsoft Azure cloud. Some of the control algorithms 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 with each other, this communication is absenting in today's smart products mostly. Communication between things and products brings new possibilities for comfortable living. For example, coffeemaker can not only turn on at a certain time but also when user parks his car at home when returning from work.

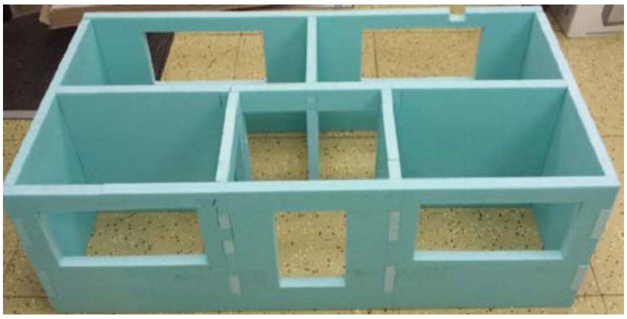

Fig.2 Basic frame of intelligent household model

During the designing of IoT products, there was an emphasis on easy installation and the capacity of the network in the household. In the average household, a home router can connect 254 nodes (elements, products, things) by wireless WiFi network or by Ethernet cable without changing any settings. Nowadays, almost every home router uses IPv4 addressing with 24 bits of address space for networks and 8 bits of address space for devices, therefore there is the limitation to 254 nodes. Many users cannot change this setting. In future, IPv6 addressing will be very important for IoT world, because IPv4 can address 4 billion nodes at max. This is 3 times less than there were connected devices in 2010. So, many devices using IPv4 works through NAT (Network Address Translation).

In addition to this, in future, we will focus on healthcare through the intelligent house. Healthcare will be ensured by controlling the atmosphere in the rooms or follow users' behavior in an apartment by a camera system and microphones (fall, scream, etc.) and based on the inputs to the system call for help [19]. Of course, in the house, there 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 model can be used in the education of IoT Systems, Cloud Solutions, Architecture of Industrial Information Systems, Single-chip Microcomputer, Computer Systems in Control and other class courses dealing with the latest technology.

In our department, we have already conducted research and development of intelligent and energy-efficient living spaces (household, office, etc.) in the past. It was a local control of house model with visualization. Research and development of this model are described in [1] and [2]. In addition, this model was used in the process of education and teaching. Therefore, there is the large assumption, that the new model will be used also for these purposes. The 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 the household are a project funded from Slovakia Tatrabanka bank funding. We named this project CASTLE (**C**omfortable **a**nd **S**mar**t** **L**iving **E**xpanded).

IV PHASES OF THE PROJECT

This project is divided into four phases. The first phase is about designing house with a necessary electrical installation. In the second phase, we have built the model of the house with electrical installation. In the third phase, we have realized temperature and light control by cloud technology from Microsoft Azure. The last phase is about the realization of the control of other elements via cloud system (for example RFID and camera system to identify objects and provide additional information).

4.1 The First Phase

This phase designs the used building materials, cabling, basic installed elements, ground plan, wiring project for the model of the house. Besides, the first phase creates a simulation model for a physical model of the household in the 3D environment.

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 the house uses 12V and 24V DC electrical installations because we use actuators and sensors with mentioned voltage. Also, 220 V AC is dangerous for the scale model of the house. Basic installed elements are intended for thermal and light systems (temperature sensors, peltier cooling/heating modules, blinds with drive, LEDs, etc.).

The simulation model is visualized in object-oriented language C# through Unity environment. We can simulate a thermal system, through the simulation model of the household. The algorithm of temperature control is programmed and simulated in Unity 3D environment. Simulation model includes thermal throughput of polystyrene, wood, and plexiglass. We use fuzzy regulation for temperature control in the simulation.

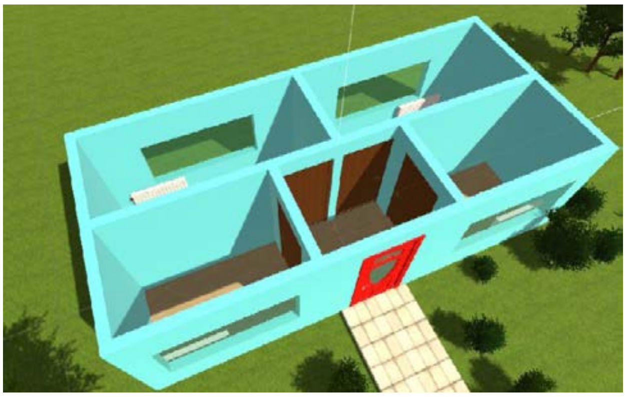

Fig.3 Simulation model of household

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

4.2 The Second Phase

During the second phase was built the model of the household. The procedure is described in the description of the model. The basic frame of the intelligent household model is in figure Fig. 3. Laminate flooring is elevated from the bottom to add more sensors and actuators. Realization of the switchboard is included in this phase. The main switchboard for our model is in figure Fig.4.

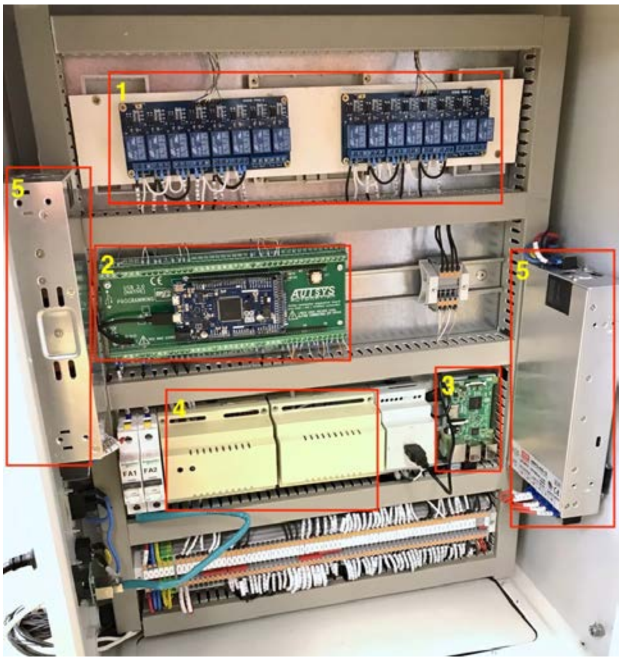

Fig.4 Switchboard

The control unit of the switchboard (Fig. 4) is Arduino Mega (2). Raspberry Pi (3) ensures communication with cloud and is connected with Arduino by the serial link. Relays (1) are used for thermoregulation. H-bridge controllers (4) are used for light regulation. At both sides, there are power supplies (5). Arduino Mega (Fig.5) is a device that cannot connect itself to the internet. So, for connection to the cloud Raspberry Pi 3 is used. Arduino Mega and Raspberry Pi communicate with each other by serial connection.

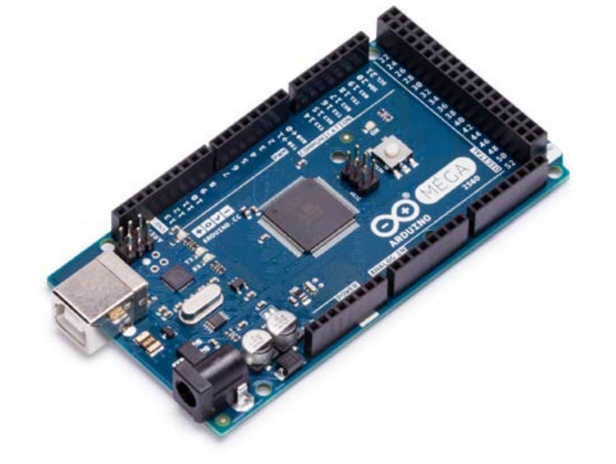

Fig.5 Arduino Mega

Sensors and actuators for thermal and light systems were developed during this phase. The thermal system consists of temperature sensors and air conditioning unit. Scale model of air conditioning unit (Fig.6) is made from modules that use peltier effect. Peltier modules are between two heatsinks. Better heat transfer is ensured by the use of the heatsinks with fans (active coolers). The light system consists of LED strips, blinds, and photo-resistors.

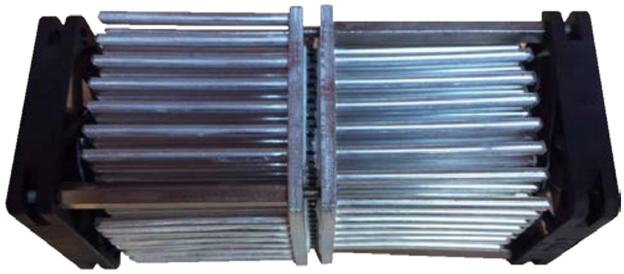

Fig.6 Air conditioning unit for our model

We developed PCB (printed circuit board) with the socket for Arduino Mega (Fig. 5, Fig. 7), this socket is also fully compatible with other Arduino boards. PCB is connected via copper cables with other PCBs and connectors blocks. The PCB was created for better handling and connecting cables to the controller.

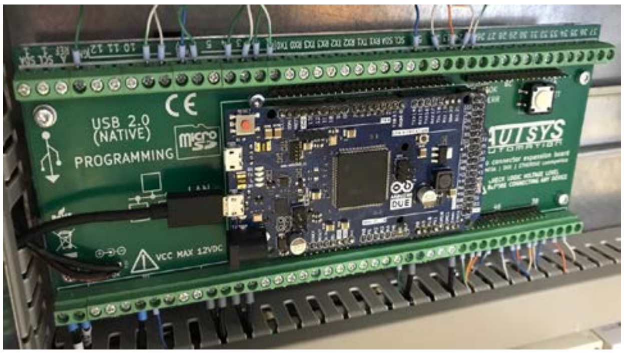

Fig.7 PCB with socket for Arduino

Four channel H-bridge Controller (Fig. 8) is PCB developed for light regulation (blinds motors and LED strips). This PCB allows connecting actuators to the controller with power supply from 5 to 35V at a maximum current of 2A per channel. H-Bridge Controller is placed in a standardized box for the switchboard.

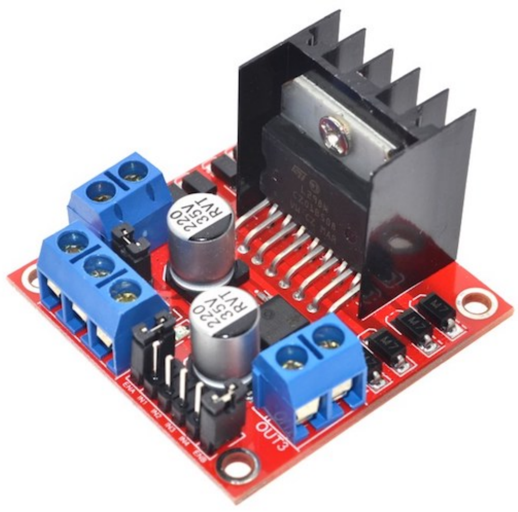

Fig.8 H-bridge controller board

Relays (Fig. 9) is developed for thermoregulation (peltier modules, fans on heatsinks). The maximum supply voltage is 30V DC and current consumption 10A. The controller is placed in the same standardized box for the switchboard. At first, the H-bridge modules was also used for thermoregulation control. After testing, the conclusion was that these modules always run on full power because of quite a low efficiency, so relay modules were a better choice to reduce cost.

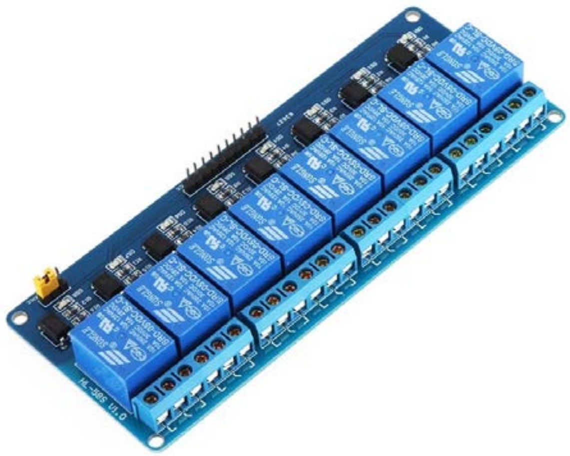

Fig.9 Relays

Mentioned PCBs can be used on other devices with the power supply to 30 Volts. During this phase, there were also developed others PCBs and improvements of sensors and actuators. Two power supplies are installed in the switchboard, the first supply operates at 12V, and the second supply is at 24V. The physical model is shown in figure Fig. 10.

Fig.10 Household model - CASTLE

4.3 The Third Phase

When we have constructed the model with sensors, actuators, switchboard and we have simulated the thermal system, we can program this control to the cloud system. This control is programmed as a service through Microsoft Azure.

At first, we also want to implement light control to the cloud but LED strips require very low latency in order to make transitions smooth. We decided to split light control to two parts. The first part, control of the LED output, is made locally in Arduino Mega by use of the PI controller algorithm. The desired values for this controller is received from the cloud. Also on the cloud are decided when to automatically close blinds as follows: if the amount of light in the room is lower than desired value than the blinds are opened, if it is not enough than LED strips are turned on. Also, if there is more light inside the room than outside of the house, blinds are closed to ensure privacy in the household. Moreover, a user can decide if he wants to allow automatic blinds, maybe he always wants to have blinds opened or closed, then light intensity is controlled only with LED strips.

This phase has many options of realization. These options are described in the next chapter named *Models of Control*. This service will be enriched by control of IoT products developed in the fourth phase.

4.4 The Fourth Phase

At this phase, there will be designed other IoT products, which will be used in the future. 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 the design will propose devices individually from appearance design, via electronic proposal, to material design. Finally, all proposals will be implemented and installed on the model of the household. To better suits needs of the household. These devices will be connected to the cloud from Microsoft Azure. Communication protocols will be set and programmed. Regulation and control algorithms will be programmed for designed IoT devices (products, things). Creating a web-based HMI (human-machine interface) environment for the user will be also necessary (in addition to the necessity for control services). This web page (used for HMI) will be part of the cloud system creation. For a long time now, HMI is not just a matter of industry applications. Search, design, and programming of possible interactions between elements in the home will be part of this phase. Many sensor and actuators make possibilities for multi-agent systems with interactions that we nowadays cannot even imagine.

We are already testing additional sensors placed in the household based on the Bluetooth Low Energy (BLE) technology. The key advantage of BLE comprises low energy consumption. A main advantage of the using BLE beacons is that the proposed solution is the client-side power efficient since the iBeacon protocol is built upon BLE, a highly power efficient version of the Bluetooth standard protocol. iBeacon is a protocol developed by Apple company in 2013. Various vendors have since made iBeacon - compatible hardware transmitters - typically called beacons - a class of Bluetooth low energy (BLE) devices that broadcast their identifier to nearby portable electronic devices. Most importantly, the technology enables a device to make extremely precise determinations of what is nearby. Any device with Bluetooth 4.0 (or later) hardware is capable of acting as a beacon, the investment required for hardware is only a few dollars. [28]

We are also implementing energy monitoring to this model of the household. Complete smart metering solution consists of three main units. The first one is the measuring unit that is made from clamp on sensor and development board. Cloud services that are used for data gathering, transformation and storing are the second part of the system. Analysis and visualization of gathered data is the last part. Data without its representations doesn't bring any value. So that we decided to visualize measured data in the user-friendly form. The main goal of the whole smart metering system is to provide information about energy demand in real-time but it also need to give us information about summarized values like total consumption and price for consumed energy. Designed system fulfill both these requirements and provide additional functionality like the prediction of consumption for next day and notification about overconsumption. From gathered data, we also can predict failure of some appliances. For purpose of data visualization and modeling, we used Microsoft Power BI tool.

Nowadays, WiFi modules can be as small to be implemented almost everywhere and cost can be lower than 1 Euro. This will ensure easier implementation of IoT products because there is no need for additional infrastructure. IoT products can be installed wherever where traditional products are installed at no additional cost.

We are still working towards completion of this phase.

V MODELS OF CONTROL

The first idea was to keep the whole control algorithms of the house on the cloud. This model of control works, but household becomes dependent on the 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 (nowadays cloud 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, as 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 the public cloud,
- control and HMI through the private cloud,
- control and HMI through the 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 as a service but 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 this term was used in [4] and [5]. Imagine an environment where IoT devices perform only basic computing and cloud services as the CaaS perform control and manage interconnection between IoT devices. In our opinion, this is ubiquitous computing in the wider sense. Ordinary users will feel ubiquitous computing, but they do not know where ubiquitous computing is. They do not need to know where it is because it will be ubiquitous.

5.1 Control and HMI through Public Cloud

We use services of Microsoft Azure for control and HMI through the public cloud. Microsoft Azure has special services for IoT products. Some of them are IoT Hub, Event Hub, Stream Analytics, etc. There are other companies offering similar services, for example, IBM with IBM Bluemix and their Watson IoT Platform or Amazon with Amazon Web Services.

We have implemented three types of architecture:

- Raspberry Pi as IoT gateway with Windows 10 IoT core installed communicates by MQTT protocol,
- Raspberry Pi communicates by HTML requests with the cloud system,
- Arduino with Ethernet module communicates by MQTT or AMQP with the cloud system.

The first architecture was presented at Microsoft IoT Hackathon in Bratislava, Slovakia by our research group. All IoT devices were connected to Raspberry Pi by Ethernet, WiFi, Bluetooth, and other interfaces. Raspberry Pi sends all information from sensors to public cloud by MQTT protocol via service named Event Hub. Our solution uses Microsoft Azure as public cloud. This information is transformed by service Stream Analytics. Then it is stored in the NoSQL database, and presented by the web page (HMI). The last step sends information to devices (actuators) to take action. Described scenario is shown in Fig. 11.

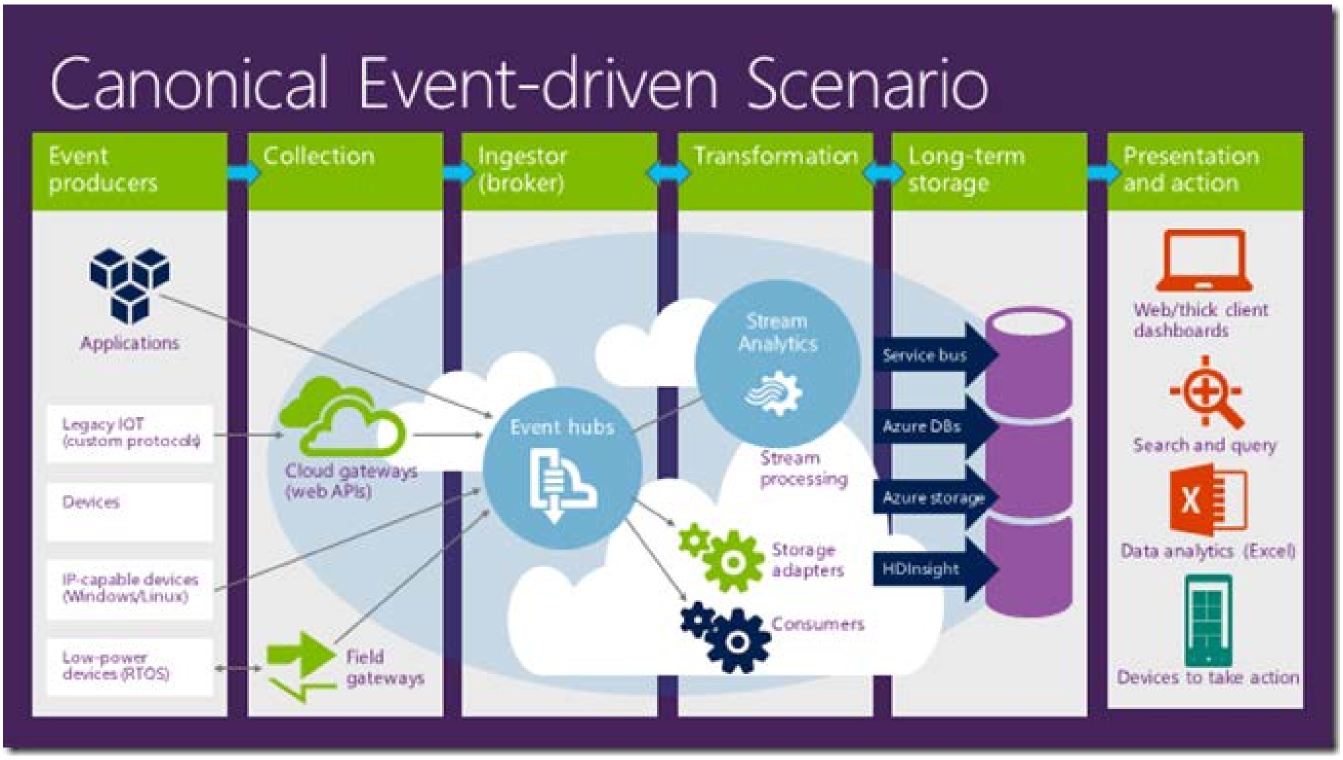

Fig.11 Canonical Event-driven Scenario [13]

The second architecture is used on our household model. Raspberry Pi collects data from all devices in the house. This data is then sent to the public cloud as an HTTP request. Cloud service evaluates this request: store data to the database, dynamically change HMI web page and calculate control variables for actuators in the house. These variables are sent back to Raspberry Pi as an HTTP response.

The last architecture is similar to the first architecture, but Raspberry Pi is used without Windows 10 IoT Core but with some other operating system, for example, Raspbian Linux based operating system. The architecture uses MQTT or AMQP protocol, Event hubs (for example Microsoft IoT hub), Stream Analytics, etc. (Fig. 11). This last architecture is the best according to the latency. We used the second architecture, because this model is used for education, and RestAPI is a more general solution than Events hubs from Microsoft. It is easier to edit by the student in the class, and easier to create own solution.

At first, we used EtherDue microcontroller for both the control and communication with the cloud. Due to the limited computation power and memory capacity, the combination of the Arduino Mega and Raspberry Pi proved to be better.

In this solution (Fig. 12), web page (HMI) and control algorithms are running on the public and remote cloud system. All information from sensors is sent to cloud and all information to actuators is received from the cloud from household through the gateway.

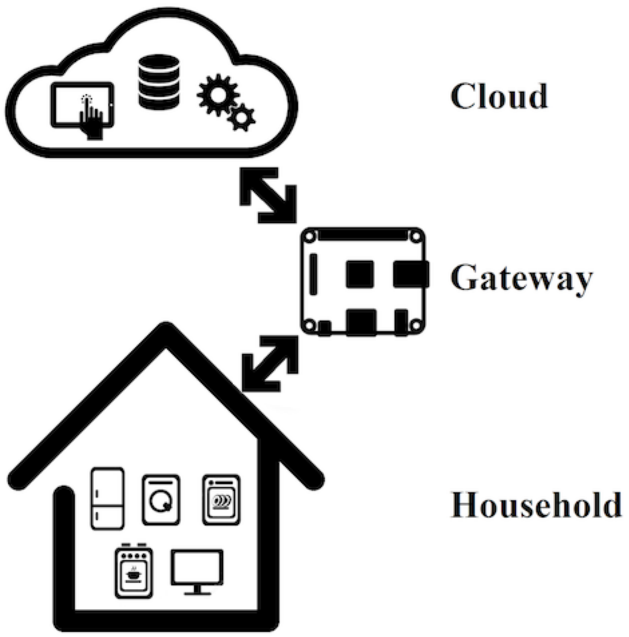

Fig. 12 Public cloud solution

This solution is fully dependent on the Internet connectivity. The fully interactive 3D model that can be used to control devices in the household can be seen in figure Fig. 13. State of the devices can be changed by clicking on them.

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 web page for the household.

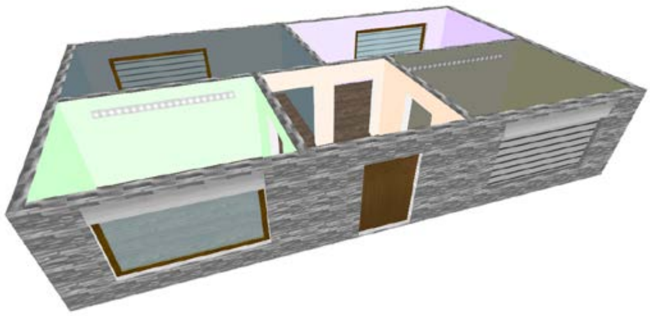

Fig. 13 Part of web page (HMI)

5.2 Control and HMI through Private Cloud

User (or integrator) can build own server, which will control user's household. If the user uses classical server or personal computer, then the solution is not economical because a classical computer has an average power consumption of about 400 W (from 200 W to 700 W), that means about 3500 kWh per year. If the user uses a notebook as a server, then average power consumption is 50 W that is mean 425 kWh per year, that is better than PC but it is also quite high. But when microcomputer like Raspberry Pi is used (Fig. 14), then power consumption can be as low as 5 W that is approximately 44 kWh per year, that is 80 times lower than it is with PC. This shows that the cost reduction for electric energy can be quite high.

When we want to use the home server, we need public and static IP address. Most Internet providers use dynamic or private IP address because they want to provide the Internet to many people with small address space.

Fig.14 Raspberry Pi model 3

If we use the private address, then control will function only in local home network and the user cannot control house by HMI outside of this network. If we use the dynamic address, then we have to know our actual address every time, when we want to connect to our house. If we have static and public IP address at the same time, we can implement our solution of control by the private cloud. Control algorithms and HMI web page are programmed on Raspberry Pi and every IoT product has to communicate with Raspberry Pi. Raspberry Pi is the web server and the household controller hub at the same time. This solution is not dependent on the Internet connectivity. When Internet connectivity is lost, the user cannot connect to HMI outside the home network, but control is running. The best scenario is to combine public and private cloud solutions (hybrid cloud). Security and safety are in charge integrator in this case.

In this solution (Fig. 15), web page (HMI) and control algorithms are all running on the private cloud system.

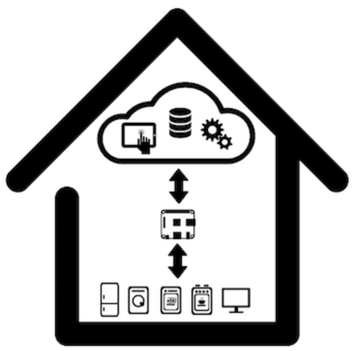

Fig. 15 Private cloud solution

5.3 Control and HMI through Hybrid Cloud

This model has distributed control algorithms and HMI web page. One part of the control algorithms (controlling of the LED luminosity) is running on the private cloud and other run also on a public cloud (overall light control, heating control). HMI is running on the public cloud. Static and public IP address is not important because communication between clouds provides HTTP requests. Private cloud is an HTTP client, which is sending requests to HTTP server (public cloud) at predefined time intervals.

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

Safety is in charge integrator as in previous options. In this case, the provider of web services is responsible for security.

The first and the third *model of control* can use IoT gateway for distribution of data, and SOA (service-oriented architecture) for data acquisition and data processing. Our research group is researching and developing these technologies, what can be seen in [6], [7], and [22].

HMI now run on the public cloud so, the actual solution is highly dependent on the internet connection. Duplicating HMI and control to private cloud (Fig. 16) can be one of the solutions to this problem. When there is no internet connection HMI will be displayed temporarily from a private cloud. The user can maintain control over the devices in the household. The limitation is that HMI will be available only on the local network. Mobile network module (2G, 3G or 4G) can be used to overcome this limitation and send critical data when needed.

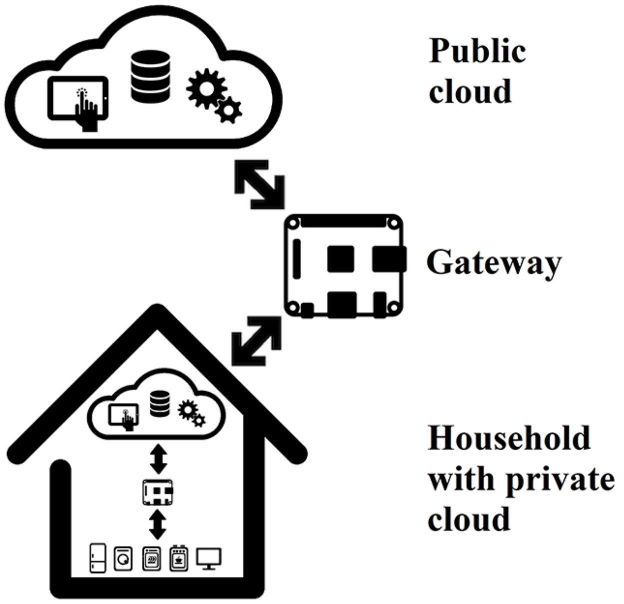

Fig. 16 Hybrid cloud solution

VI MACHINE TO PEOPLE INTERACTION

M2P (machine to people) connections mean that people can send information to technical systems and receive information from these systems. M2P connections are transactional, which means the flow of information moves in both directions, from machines to people and from people to machines. [27]

HMI is based on information that flows between machines and people. All *models of control* can use one interface for machine to people interactions. We used multiplatform programming languages to create an M2P interface (PHP, HTML, C, C++, CSS).

Basic state of the devices can be visualized and controlled by the interactive 3D model of the household (Fig. 13). Advanced parameters of the IoT devices in the household are visualized and controlled by the user interface with sliders and switches. Currently, there is implemented control of the lights and heating in all four rooms of the household.

In the figure (Fig. 17) is shown interface for light control. We can turn on or off the automatic blinds control, set the desired value for luminosity in each room, turn on or off the light completely, set power output of LEDs and manually open or close the blinds.

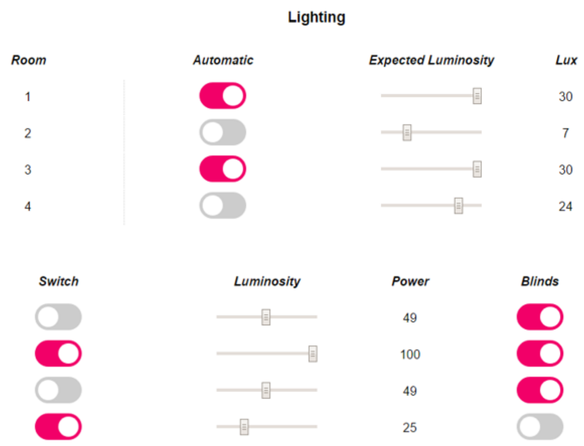

Fig. 17 Light control HMI interface

In the figure (Fig. 18) we can see the interface for heating control. There are switches for automatic heating or cooling of the room, slider for setting the desired temperature, actual temperature and then switches to manually set heating or cooling.

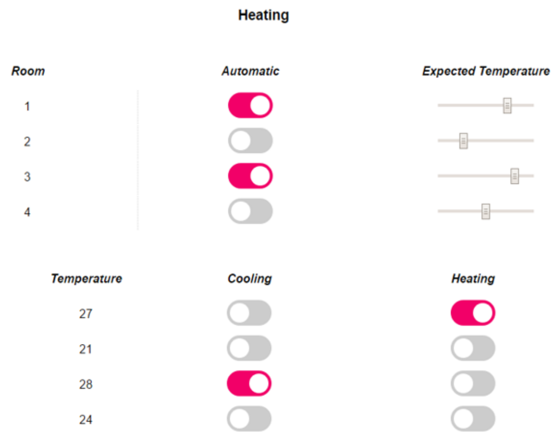

Fig. 18 Heating control HMI interface

M2P technologies can range from automated notification systems with preset triggers, to advanced dashboards. Users can also perform more complex M2P operations such as examining and analyzing received data and determining how to present information to decision-makers.

We plan to use beacon technology mention in *The Fourth Phase* to further enhance the comfort of the user by automation of another task, like turning on lights when user come to room or opening the doors. Moreover, HMI interface on the mobile device can be adjusted according to user position to display only the relevant information. This implementation has also potential in intelligent buildings to localize, identify or navigate persons (employees, tenants, workers, etc.) as described in [29]. An idea of the proposed method for indoor route guidance using beacons module can be seen in figure (Fig. 19).

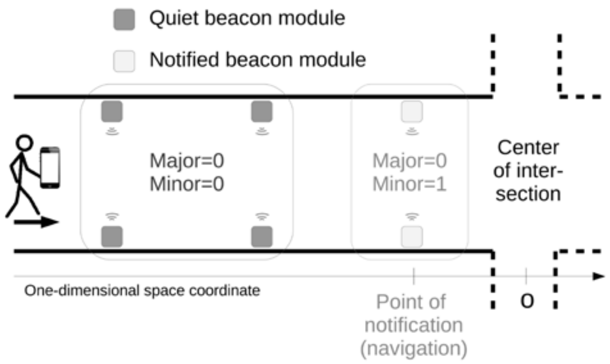

Fig. 19 Indoor guidence with beacons modules

VII RESEARCH AND DEVELOPMENT IMPACTS

Thanks to this project development in two directions occur 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 we can control and set requirements of the household. So, the user can control the particular thing at home on a tablet, laptop, smartphone or other devices which can display the web page. Such control would not be necessary to develop separately for each household. It could be developed only one time and then it can be deployed for users to keep an eye on their households.

The 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 algorithms could be used for any household.

7.1 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 the smart home with all installed IoT elements connected to the global network, Internet. This smart home with IoT elements is controlled from a web browser and it is regulated and controlled remotely. The technical solution also includes various IoT elements, which were developed under the project CASTLE. Until now, we developed:

- thermo-regulatory elements made of peltier modules, heatsinks, and fans,
- the system of temperature sensors,
- light system: the system of actuators (blinds, LED lights) and sensors (photoresistors),
- switchboards.

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.

VIII CONCLUSION

This paper defines three models of control for IoT residential and business premises and describes implementation methodic. Moreover, our research group has built a scaled household model using described methodic.

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 from the production sphere since in this area inspiration cab be found. Also, a platform of application developed during this project foresees the significant potential for commercial use.

Project CASTLE (model and concept of system creation) has a high envisages to be used in the 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 class 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 based on the technologies that will be tested on the scaled model. We want to 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. IoT network itself creates ubiquitous computing, but if it adds interconnection with cloud technology and CaaS, then ubiquitous computing is expanded.

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