Intelligent Space at Center for Intelligent Technologies – System Proposal

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Abstract—**In this paper we present an engineering proposal for a data processing system based at the Center for Intelligent Technologies. The proposed system forms the Intelligent Space using the collection of sensors including IP cameras, Kinect sensors and other. The proposed data processing infrastructure is based on the Fog Computing paradigm established by Cisco. The main reason for utilization of this approach is the necessity to process large amounts of data produced by the sensors within the considered Intelligent Space. Such amount could not be processed using typical Internet of Things solutions which rely heavily on remote Cloud Computing. The paper provides detailed description of hardware, software and networking solutions and also provides a couple of example applications within the implemented Intelligent Space.**

I. INTRODUCTION

The Internet of Things (IoT) is commonly accepted paradigm that "considers pervasive presence in the environment of a mutually interconnected devices that are able to interact and cooperate with each other in order to create new applications or services and reach common goals" [1]. This interaction and cooperation is based on certain types of communication which can be either [1]:

- Human to Machine (H2M),
- Machine to Human (M2H),
- Machine to Machine (M2M).

An Intelligence Space (IS) is a specific manifestation of IoT in which "the actions of numerous networked controllers controlling different aspects of a common environment are orchestrated by pre-programmed pre-emptive processes (e.g., intelligent software agents) in such a way that it enhances experiences and capabilities of its occupants," either humans or machines [2]. In this paper, we aim to outline a specific proposal for such intelligent space and show selected examples of use cases and applications within it.

The rest of the paper is organized as follows: In the following part of the introduction we introduce the main paradigms which influence the proposal and also describe the specific location in which the implementation takes place. The second section presents the proposal itself. In the last section, we conclude the paper with selected specific use cases of the proposed Intelligent Space.

A. IoT Related Paradigms

The implementation of IoT is tied very closely to progressive application of cloud computing tools and methods. According to NIST definition [3]: "The Cloud computing is "a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources such as networks, servers, storage, applications, and services that can be rapidly provisioned and released with minimal management effort or service provider interaction."

Cloud computing can be used for storing and accessing data or programs over the Internet instead of local computing infrastructure. It provides resources such as virtual machines or data storage, which are often convenient alternative to locally installed hardware and software which can be expensive and there is also maintenance to consider. The cloud therefore removes the need for user to be in the same physical location as the hardware that stores the data [4]. Cloud-based backup is also very useful service that can be scheduled to run automatically and all important information is stored in a remote location in a safe and secure environment. Recovery solutions can be used to recover files, programs and data from the Cloud [5]. However, the cloud solutions also have disadvantages especially in case of transferring and processing large amounts of data. The solution of this problem can be found in utilization of Fog computing.

Fog Computing is an advanced or extended version of cloud computing where the computing takes place at the edge of the network, close to either clients or sensors [6]. It was introduced by Cisco and defined as an extension "of the Cloud computing paradigm from the core of network to the edge of the network." It is a highly-virtualized platform that provides computation, storage, and networking services between end devices and traditional cloud servers [6]. Main idea of this approach is depicted on Fig. 1.

Fog Computing aims to be the solution to the concerns like the ability to interact in real time with incoming data or the requirement to work within the limits of available bandwidth [7]. There is a lot of data being generated these days and it is often too much to be sent to the cloud. Even in cases when it is possible, it costs too much to do that. Therefore, we need to use Fog computing to evaluate, filter and preprocess the data before it is sent to the Cloud and vice versa [7].

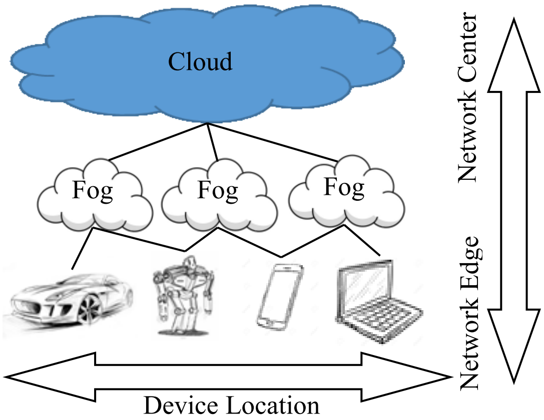

Fig. 1. Fog computing paradigm

B. *Intelligent Space Location*

The implementation of the proposed Intelligent Space is executed at the Center for Intelligent Technologies (CIT). The center was established in 1995 and subsequently become a member of Center of Excellence and also a Competence Center for Knowledge based technology at Technical University in Košice, Slovakia [8]. The main goal of CIT is the promotion of new trends in computer sciences and information technologies and also to support the applications of intelligent technologies. Areas of interest include human-robot interaction, tele-operation, learning by example, emotion technologies, advanced image processing, robot-internet interface (including cloud applications) and many other issues. The focus is based on the tools of computational intelligence, such as Fuzzy inference systems [9], Evolutionary Computing [10], Neural Networks [11] and other biologically inspired approaches. The center contributes to the creation of a software framework for Internet of Things which includes robotic control, ambient robotics and its applications in smart spaces and houses [8].

II. INTELLIGENT SPACE AT CENTER FOR INTELLIGENT TECHNOLOGIES

A. *Utilized Hardware*

The implemented Intelligent Space will make use of several types of sensors, including 16 IP Cameras with microphones, 6 Kinects and also other IoT sensors, for acquisition of environment variables such as light intensity, temperature, air quality, loudness, ultrasound, infrared light, etc. In addition, we expect utilization of RFID cards and readers, E-beacon technologies and more.

As a basis of the computing infrastructure, we assume the utilization of two main servers, six mini-PCs which will process the inputs from Kinect sensors and several other PCs serving as dedicated micro-servers, mostly for tasks of remote monitoring and control (i.e. M-H and H-M interaction). Simple monitoring web-application is shown on Fig. 2.

Fig. 2. Camera monitoring system in CIT.

Since our center is oriented towards research in robotics, we aim to utilize service robots such as TheCorpora Qbo, Robotnik TurtleBot and Hanson Zeno, but also other robots including simple Lego Mindstorms NXT and EV3, and last but not least older models such as Sony AIBO and Aldebaran Nao accompanied by custom sensor-enabled automobile as can be seen on Fig. 3. For simple and unified control of these various models we expect the application of Robot Operating System (ROS) which offers universal remote control via convenient REST API.

Fig. 3. Robotic hardware at CIT – top left to bottom right – AIBO, Nao V1, Nao V3 in customized sensor-enabled automobile, TurtleBot, another AIBO and Qbo.

B. Underlaying Network Infrastructure

The network infrastructure of proposed Intelligent Space consists of two local area networks bridged by two servers. The first, hidden network (LAN1) connects the cameras and Kinects to the servers via high capacity 1 Gb/s optical connection. The cameras and sensors are installed at the hallway leading through the CIT laboratories and offices. Data and power circuits are laid above the ground floor in between the roof and the hallway soffit. The data circuits are depicted on Fig. 4. The second, publicly open network (LAN2) (which includes also a WLAN interface) connects other devices, including low bandwidth (wireless) IoT sensors, robots, user PCs and other clients. The access to video streams from the cameras and the Kinect sensors (connected to LAN1) is possible only via the mentioned servers. This setup is well suited for utilization of fog computing techniques.

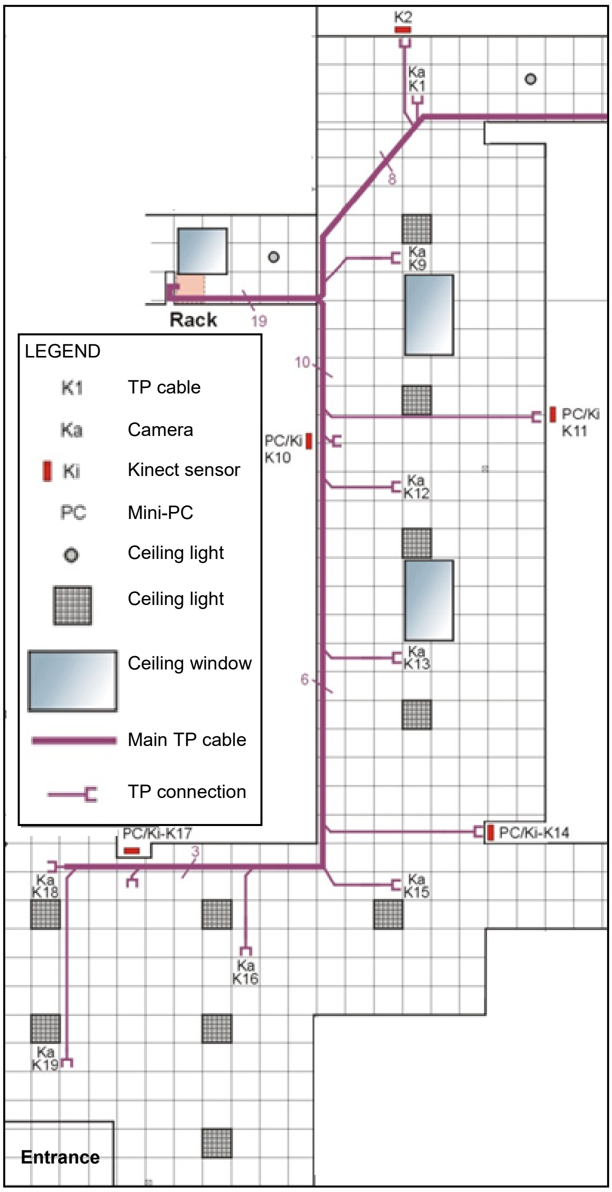

Fig. 4. Partial schematic of sensory equipment in CIT – cameras and Kinect sensors – forming dedicated LAN for data transmission towards data-processing fog computing infrastructure [12].

C. System proposal

The implemented Intelligent Space will gather various data including video streams, depth map streams (from Kinects), audio (from microphones built in cameras and Kinect) and other data from remaining sensors. Therefore, it is necessary to define viable strategies for transmission, processing and storage of this data. A general proposal for Intelligent Space in CIT is depicted on Fig. 5. It complies with physical network infrastructure, since it expects that most of the data processing will be done on two fog computing servers, one of which will host the data storage.

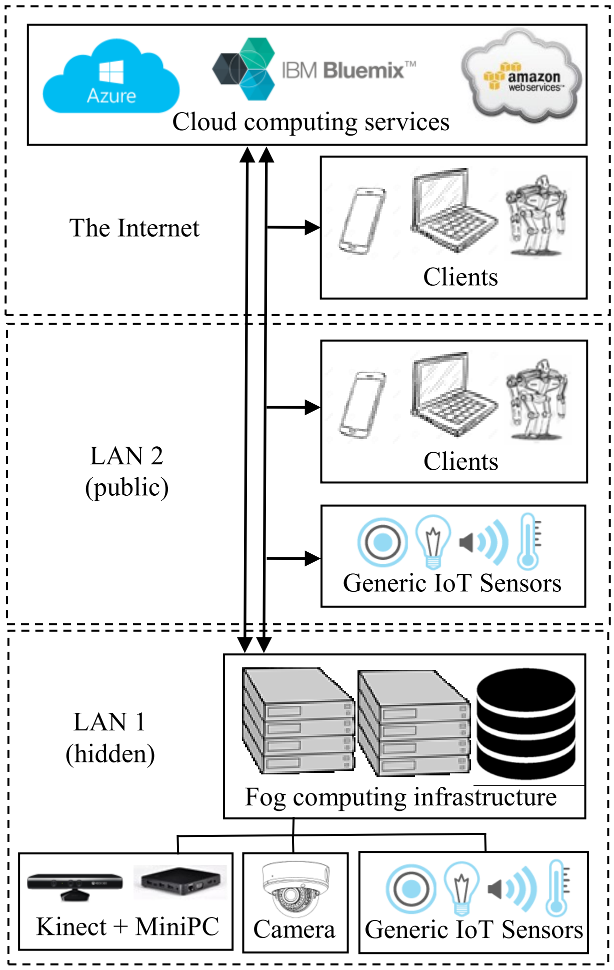

Fig. 5. Intelligent space at CIT – Networking proposal

In order to calculate a projected data flow from sensors, we estimated that IP cameras produce MJPEG streams of HD video at rate of approximately 10 Mb/s for each camera. Kinect sensors produce streams which are at least 1,6 times as much (colored image + grayscale depth map + contour image). With a total count of 16 cameras and 6 Kinects and estimated data generation at a rate of 250 Mb/s, it is definitely not feasible to perform its processing using cloud services, and therefore it needs to be done locally using fog computing infrastructure.

For audio acquisition and processing we consider an option to use cloud services directly, since these are not so bandwidth demanding. Same applies to other data acquired by remaining IoT sensors. This idea is depicted on Fig. 6.

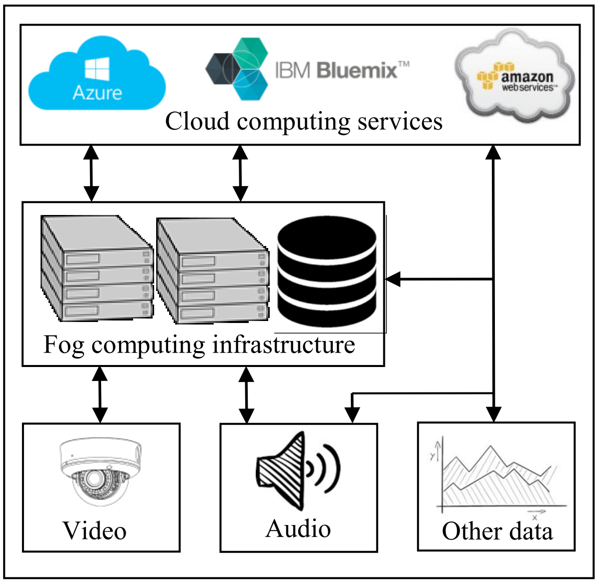

Fig. 6. Intelligent space at CIT - Data processing and storage

As a data storage, a local No-SQL database is being considered for unstructured data such as video and audio streams and SQL database for structured data or information produced by employed analytic services.

III. Sample Applications for Proposed Intelligent Space

Since the possible applications in Intelligent Space are numerous, we will focus only on the most obvious applications related to video and audio processing.

A. *Audio processing*

The emotion detection either from video, audio or text is currently a very active research topic [13]. In Fig. 7 we propose a system that will use microphones in cameras and Kinects in order to convert the spoken language into text strings and concurrently detect and assign the sentiment according to the result of emotional analysis.

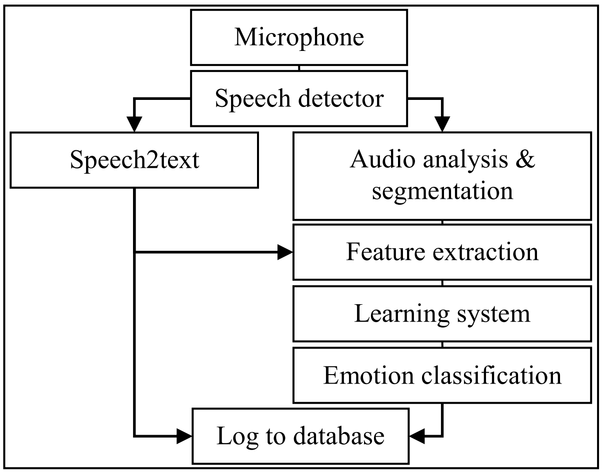

Fig. 7. Proposal of speech emotion recognition & text transcription system

For the speech2text conversion we propose the utilization of the state-of-art Google speech API. The emotion classification will be performed using suitable machine learning method.

B. *Video processing*

We have already presented a sample monitoring web application shown in Fig. 2. However, this application renders video directly from cameras and hence overloads the network by additional data traffic. Similarly, such continuous recording is also demanding on data storage.

Therefore, we would like to implement a system which will save up the network bandwidth as well as server disk space. The proposed system is supposed to be run on the Fog Computing servers and provide users and other services with on-demand access to video streams from cameras placed within the Intelligent Space.

IV. Conclusion

In this paper we introduced a proposal for an Intelligent Space which is being constructed at the Center for Intelligent Technologies at Technical University of Košice. We have described the background of used technologies and methods, specifically the concepts of Internet of Things, Cloud Computing and Fog Computing. We have also outlined the overview of the proposed infrastructure along with its hardware and software components and provided illustrative figures of projected networking connections.

Our goal is to use this space in order to solve research tasks related to the Internet of Things, cyber-physical systems, robot localization and remote control (either via humans or network services). We have presented a couple of these in section III of this paper, however, the list of possible application goes much further. In the initial stage, we aim to formulate a suitable scheme for long-term data storage using SQL and No-SQL databases and its processing using Cloud and Fog computing services.

The effort is being made to implement a service which would send continuous data the from Kinect sensors in the form of video streams consisting of original images, depth maps and contour maps using RFT protocol. Another goal is to establish a Fog service which would rebroadcast these streams to users and cloud services. And last but not least, we are yet to consider the usage of specific IoT hardware, such as Wi-Fi, RFID and E-Beacon localization technologies, specific sensors of environment variables including light intensity, temperature, air quality, loudness, ultrasound, infrared light, etc.

Acknowledgment

This research work was supported by the Slovak Research and Development Agency under the contract No. APVV-015-0731 and research project is supported from 07-2016 to 06-2019.

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