# Integrating VoIP Systems with The Internet of Things

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***Abstract*—With the rise of the Internet of Things (IoT), Voice over IP (VoIP) systems can be integrated into the IoT gateway to communicate with things over a telephone network. Integrating VoIP systems with the IoT will become very useful in many scenarios such as auto-dialing a phone number for an emergency event, controlling IoT devices via analog phone and monitoring smart objects via VoIP phone. This paper introduce a novel, low cost solution to communicate with IoT devices over telephone and mobile networks as well as the Internet. We present the design and implementation of this solution to show the benefits of VoIP systems for the IoT. Evaluation results have shown the applicability of proposed system for telephony, home automation and security.**

***Keywords*—Internet of Things, VoIP system, Home automation.**

## I. Introduction

The Internet of Things (IoT) is considered as a key enabling technology for the future. The IoT refers to the billions of devices connected to the Internet. A thing, in the IoT, is a *smart object* that can be assigned an IP address and provided with the ability to share data over a network. Smart objects typically have limited capabilities in terms of computation and memory and use low-power to operate and communicate.

Internet Protocol (IP) is the common network protocol for the IoT devices to communicate with each other. IoT devices that can not run IP stack, such as light bulbs, door locks and sensors, are connected to the network through an IoT gateway or hub. However, all the remaining devices are interconnected over IP-based networks.

Voice over IP (VoIP) involves the transmission of voice over an IP-based network, the phone itself may be analog, digital or software-based (softphone). The VoIP system is connected to VoIP gateway as well as to the telephone network (PSTN). The VoIP gateway allows the phone calls to be completed through the IP network. The enterprise may use the IP network to make all phone calls between its local and remote offices or split the voice communication between the IP network and the telephone network.

Since IP is the core protocol for the IoT and VoIP, VoIP systems can be integrated into the IoT gateway to communicate with things over the telephone network. Integrating VoIP systems with the IoT will become very useful in many scenarios such as auto-dialing a phone number for an emergency event, controlling IoT devices via analog phone and monitoring smart objects via VoIP phone. In this paper, we will introduce a novel, low cost solution to communicate with IoT devices over telephone and mobile networks.

This paper is organized as follows. Section II provides a background of Internet of Things and VoIP. Section III explains smart VoIP system. Section IV describes the design and implementation of proposed system. Section V describes our testing scenarios and evaluation.

## II. Background

### A. Internet of Things

The term "Internet of Things" was first proposed by Kevin Ashton in 1999 to describe an RFID system, which is connected to the Internet. Ashton was describing how the Internet is dependent on human being for collecting information, by typing, taking a picture or recording a video. While, the Internet of Things is based on computing devices that have the ability to collect information from the physical world without human interaction [1].

Today, Internet of Things (IoT) become a global network infrastructure of objects with identification, sensing and communication capabilities based on several information and communication technologies such as RFID, Bluetooth and Wi-Fi. Things in the IoT include many physical objects like sensors, actuators and other devices that can be connected to wired or wireless networks and sharing data. These things can collect and process data, respond to control inputs and transfer data over the network [2].

Internet of Things transform everyday objects in our environment to smart objects that can share data with other members of the network, often using the IP connectivity. In this way, smart objects are acting and reacting autonomously in their environment and having the ability to communicate with each other and exchange information with people [3].

All of the things in the IoT have an IP address and are able to interact with each other over the network. Things that can not run IP stack, such as light bulbs, door locks and sensors, are connected to the network through an IoT gateway, which connects things to the cloud [2].

The IoT applications involve solutions for monitoring, remote control and automation. These applications provide access to information through wired and wireless network connections, allowing users to manage smart objects from anywhere. They can also access objects anytime and anywhere through mobile network connection. As a result, the IoT will

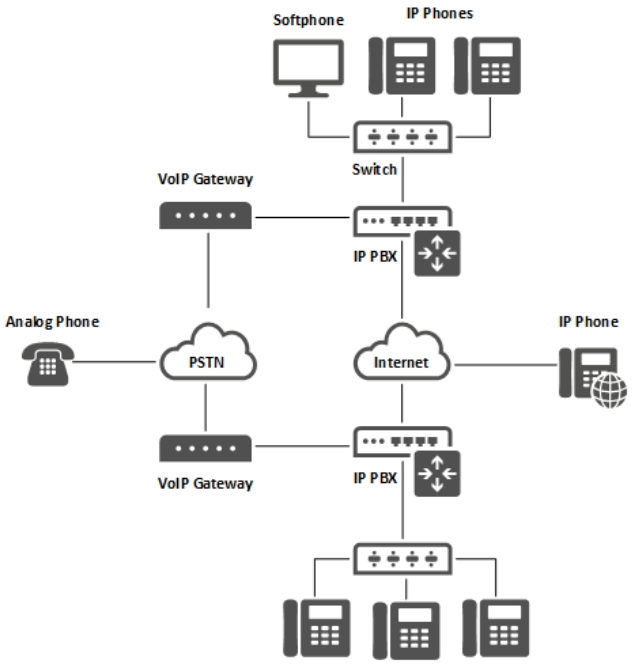


Fig. 1. IP Telephony

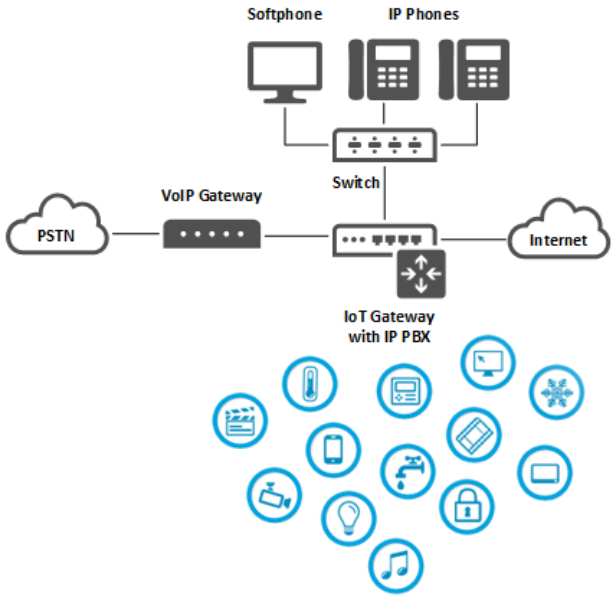


Fig. 2. Smart VoIP System

be used to solve challenges in different areas including cities, energy, transport, industry, health and telecommunication [4].

According to IDC, a market research firm, the number of embedded devices connecting to the Internet are expected to reach 26 billion by 2020. IDC expects that the installed base of IoT devices to grow rapidly, driven by intelligent systems that will be installed across both consumer and enterprise applications [4].

### *B. Voice over IP*

Voice over IP (VoIP) refers to the transmission of voice communication over IP-based network or the Internet. The voice is digitized and encoded in packets over the data communication network, rather than via the public switched telephone network (PSTN). IP or Internet telephony is another term commonly associated with VoIP [5], [6].

By having a common underlying infrastructure, voice and data communication can be converged over the same network. VoIP phone system, or IP PBX, can receive and route phone calls over the IP network. The VoIP system is connected to VoIP gateway as well as to the telephone network. The VoIP gateway allows the phone calls to be completed through the IP network. As shown in figure 1, the enterprise may use the IP network to make all phone calls between its local and remote offices or split the voice communication between the IP network and the telephone network [6].

In addition, VoIP systems offer a variety of features for free. Some of these features are call forwarding, call conferencing, auto-attendant and voicemail. The most attractive feature of VoIP system is cost saving. International and local phone calls become less expensive when the Internet is the transmission medium. For the enterprise, VoIP reduces the cost of infrastructure and maintenance since voice and data traffic is integrated into a single network [5].

VoIP protocols, such as Session Initiation Protocol (SIP), are able to integrate with several other application layer protocols like email and instant messaging, allowing audio and visual communication over the Internet. SIP is used between endpoints to create, modify and terminate sessions consisting of one or several multimedia streams, such as voice and video calls. The goal of SIP is to provide signaling and call setup over the IP network, which present in the PSTN [6].

## III. Smart VoIP System

Since IP is the common protocol for the IoT and VoIP, VoIP systems can be integrated into the IoT gateway to communicate with things over the telephone network as well as the Internet. To show the benefits of VoIP systems for the IoT, we designed and built a smart VoIP system that enable users to communicate with things via any phone. The system, through telephone and mobile networks, allow the user to access the IoT gateway and give him/her the ability to control IoT devices remotely. The basic idea of this system is to take advantage of telephone and mobile networks to extend the connectivity for the IoT devices.

In recent years, there are several proposed systems to increase the connectivity of devices within the home and office environment. The home devices are connected to hardware controller using different communication technologies. The controller provides interfacing and remote access to the system through the communication network. Examples include Bluetooth-based home automation system [7] and ZigBeebased home automation system [8]. However, the existing systems enable users to control and monitor devices via web browser or smartphone application.

The smart VoIP system, as shown on figure 2, relates to home automation systems that enable control of lights, doors, windows and other appliances. However, the system has the ability to route calls, collect information, interact with callers and control devices via web browser and any type of phones,

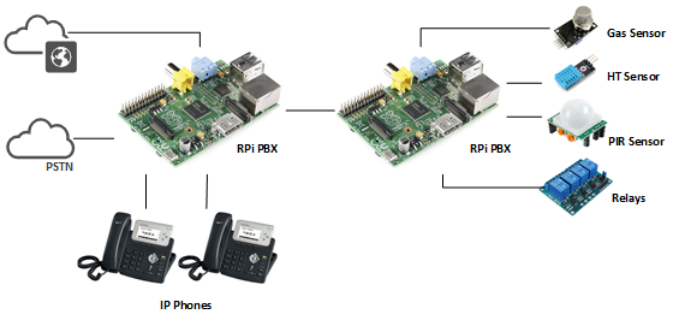


Fig. 3. System Implementation

for example, blind people can get information about their home and control home devices using only telephone keypad. The system can also be configured for home security and safety, so that on emergency event the system auto-dial a phone number and play a voice message.

Additionally, VoIP phones can be configured to accept SIP notifications from the smart VoIP system. For instance, motion sensor could notify a user via VoIP phone when motion on the area. Home devices can also be managed by the VoIP phone screen using XML feature. This feature allows the VoIP phone to serve as a user interface for system services such as turn on lights and show indoor temperature.

## IV. System Implementation

The proposed system consists of hardware and software components. The hardware is based on Raspberry Pi [9] to offer a low cost solution for implementing smart VoIP system. The Raspberry Pi is a credit-card sized computer that has the ability to interact with the physical world, and has been used in a wide array of automation applications.

There are different models of Raspberry Pi. The model B has 512MB RAM, two USB port, 26 GPIO pins and an Ethernet port. In February 2015, it was superseded by the RPi 2 model B, which shares many specifications with the RPi 1 model B+, but it uses a quad-core ARM CPU and has 1GB RAM. There are also several operating systems that can be used with Raspberry Pi, however, Raspbian [9], is designed specifically for the Raspberry Pi hardware. Raspbian is a free operating system based on Debian Linux, optimized for the Raspberry Pi hardware. It comes with plenty of software for programming. However, Python is a powerful programming language that can be used with Raspberry Pi to interface physical devices like sensors.

In our implementation, as shown on figure 3, we used two Raspberry Pi (RPi) boards, the first RPi for IP telephony and the second RPi for home automation and security. Both RPi have a 4GB SD card with RasPBX [10] image, which is based on Raspbian and contains VoIP system pre-installed. The GPIO (general-purpose input/output) pins on the second RPi is used to interface sensors and relays. Python programming language is used to read and write the pins, and to extend the VoIP system functionality to interact with the physical world by getting information from sensors and taking actions through relays.

A VoIP gateway is configured on the first RPi, allowing both inbound and outbound calls over PSTN or GSM network. In addition, a SIP trunk is configured on each RPi to connect the two VoIP systems together. So that, callers on first RPi can reach extensions on second RPi by dialing extension number directly. An extension number on second RPi is given to each controlled device to enable or disable it. For instance, 201 to turn on/off lights and 202 to open/close the door. With interactive voice response (IVR) feature in VoIP systems, callers can also interact with devices through configurable voice menus. In this way, callers are given the choice to select option by pressing digits on the phone without the need of human assistance.

The remote user can access the system through the VoIP gateway or using the Internet. The IoT gateway is integrated with IP PBX to communicate with home devices via analog or mobile phone, in addition to web browser or smartphone application. For testing purposes, Cisco SPA8800 gateway is used to connect IP PBX to PSTN. The Cisco SPA8800 also has four ports to connect analog phones to IP PBX.

To protect home devices from unauthorized users, the smart VoIP system is configured to enter a code password before taking any action. When calling an extension number to enable or disable a device, the system checks if the the password is correct. Then Python script allows RPi to turn on or off this device.

## V. Evaluation

The proposed solution was evaluated by demonstrating the applicability of smart VoIP system for telephony, home automation and security. Three controlled devices, light bulb, door lock and window opener, and three sensors, humidity and temperature (HT), gas and motion detection (PIR), have been integrated with smart VoIP system. We have investigated the following scenarios, which show some benefits of smart VoIP system for home automation:

- receive and make calls via telephone and mobile networks using VoIP gateway
- control light bulb, door lock and window opener via telephone keypad
- control home devices remotely via analog phone with password protection
- send notifications about temperature, humidity and motion on the area via IP phone
- call a phone number automatically with voice message on gas emergency case.

Evaluation results have shown the applicability of proposed system for telephony, home automation and security.

## VI. Conclusion

The Internet is moving toward connecting thing and people together. However, two-thirds of the world's population does not yet connected to the Internet. In this paper, we introduced a viable solution to communicate with things over telephone and mobile networks, in addition to the Internet, to extend the connectivity for the IoT.

For the future, we planned to add voice recognition into smart VoIP system, allowing callers to use either their voice or phone keypad to control devices over the telephone or mobile networks. Also, we will develop a smartphone application for smart VoIP system.

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