

Real-time Molecular Analysis Methods Based on Cloud Computing

Maxim Zakharov ¹, Ammar Muthanna ¹, Ruslan Kirichek ^{1,2}, Andrey Koucheryavy ¹

¹ Department of Communication Networks and Data Transmission, The Bonch-Bruевич Saint-Petersburg State University of Telecommunications, 22 Prospekt Bolshevnikov, St. Petersburg, Russian Federation

² V. A. Trapeznikov Institute of Control Sciences of Russian Academy of Sciences, 65 Profsoyuznaya Street, Moscow, Russian Federation

zaharov.spbgut@gmail.com, ammarexpress@gmail.com, kirichek@sut.ru, akouch@mail.ru

Abstract—Today, quite a lot of attention is paid to the integration of information technology and medicine. E-health network development makes it possible. The principles of e-health networks imply the use of small-sized mobile medical devices - sensors and actuators. As a rule, sensors, and actuators are combined into a network and operate with other network devices: gateways, cloud servers, etc. The article discusses the network scheme, including a portable near-infrared spectrometer for molecular analysis of food products and its interaction with the Internet in the process of data collection and processing.

Keywords— applications and services, cloud computing, e-health, internet of things, molecular analysis, NIR-spectroscopy

I. INTRODUCTION

One of the promising and constantly developing areas of modern science and technology is e-health and its applications. People tend to eat healthy and fresh foods that do not have chemical impurities and additives. In this regard, they are forced to trust food manufacturers based on information on the packaging. In connection with the development of electronics, new electronic devices have been created that can produce instant molecular analysis of the data of a product. Constantly there are a variety of portable, handheld devices. They allow you to analyse the composition and quality of food or medicines in real-time.

Most of these e-health devices, such as the personal portable infrared micro spectrometer and other, cannot perform all functions on their own, so they interact with the user's smartphone, which processes the primary data received from the e-health device and displays the analysis results in a user-friendly manner. The transfer of primary data between the e-health device and the smartphone usually takes place over short distances and is carried out using Wi-Fi or Bluetooth technology [1], [2]. Often, for more detailed analysis and processing of primary data, as well as for their accumulation and storage, it is necessary to provide interaction with a remote server via the Internet.

In order to provide telecommunications services to users of such devices in real time in compliance with the required

values of the QoS parameters, it is necessary to develop a special network architecture and rules for the provision of such services.



Figure 1. Portable personal e-health devices for food quality and composition control

The picture (e.g. Figure 1) shows several similar electronic health devices: (1) Nima [3], (2) FOODsniffer [4], (3) SCiO [5], (4) Tellspec scanner [6]. However, it should be noted that these devices are not certified medical devices.

As mentioned above, in connection with the high popularity of portable molecular analysis instruments, various applications are considered, including as part of a mobile phone. Thus, it is advisable to consider cases when large amounts of data analysis requests will be sent, for example, from a large supermarket on a day off, which will likely lead to a denial of service for some requests.

In this paper, a testbed near-infrared spectrometer for molecular analysis of food products. The remainder of this paper is organized as follows. Section II describes the testbed system structure. Section III Traffic analyses and results. In the end, we conclude our work of this paper in section IV.

II. RELATED WORKS

Currently, work is actively underway to develop various versions of wearable portable microspectrometers. These studies aim to determine the typical architecture and the main features necessary for the effective operation of such devices. The main goal pursued by the developers is to increase the autonomy and accuracy of measurements, as well as providing communication with the user's smartphone within a personal network using Bluetooth or Wi-Fi technology [7].

Active research is also being conducted in the field of miniaturization of optical components in order to reduce the overall size and energy consumption of microspectrometers, with the aim of further implementation of the microspectrometer on the chip [8], [9]. This will allow mass production of such devices and make them available for mass use.

III. QUERY GENERATION MODELS AND THEIR PROCESSING IN THE EDGE CLOUD GATEWAY

Edge gateways can be used to improve QoS performance and speed up data processing [10], [11]. Figure 2 shows the interaction architecture of the IoT system, which is divided into 4 layers.

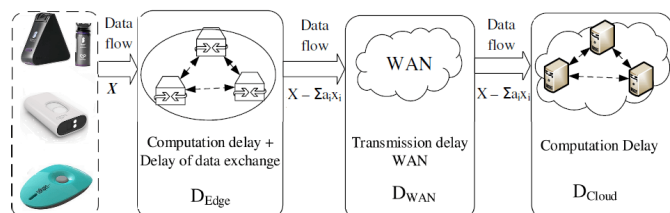


Figure 2. IoT system model

The first level is the level of e-health end-devices of the Internet of Things. These devices are connected to gateways in accordance with the user's requirements for Internet access and for interaction with other devices in the shared network. At the final an X data stream is generated that goes to the next level.

The second layer is the edge layer, which includes the edge gateways. The edge layer allows end devices to communicate with other devices and cloud servers. The edge layer also plays the role of pre-processing data before sending it to the clouds. Assume that N edge gateways accept and process the data stream X . If there is a large amount of data, you must take into account the processing time (calculation delay) and the data exchange time between the gateways.

The Wide Area Network is the third layer that accepts data transfer latency between the edge layer and the cloud servers.

The fourth layer is the cloud layer, which includes cloud servers. The cloud layer has powerful computing capabilities and a large database. Data flow that is not processed at the edge level is redirected to cloud servers. At the cloud level, there is a set of M cloud servers for processing residual data coming from the edge level. At this level, the calculation delay is taken into account for processing residual data. Thus, the system latency from the edge layer to the cloud layer

includes the data transfer delay between the edge layer and the cloud, the processing latency of data on boundary layer and cloud layer, as shown in Fig. 2. The system delay formulation is defined as:

$$D_{Sys} = D_{Edge} + D_{WAN} + D_{Cloud} \quad (1)$$

IV. TESTBED STRUCTURE

In order to assess in detail all the features of molecular analysis on the example of the SCiO NIR spectrometer [3], consider the scheme of interaction of devices (e.g. Figure 3) and the process of collecting primary data, processing them and obtaining results (e.g. Figure 4).

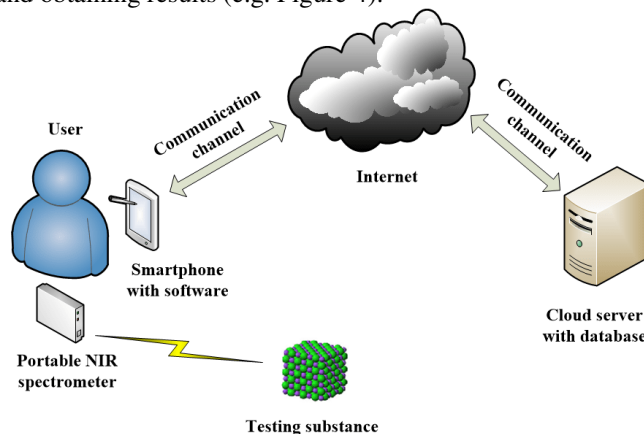


Figure 3. Scheme of the interaction of infrared microspectrometer, smartphone and server on the Internet during molecular analysis and processing of its results

Before starting to work in specialized software on a smartphone, the user must pass the authentication procedure on the developer server. This is necessary in order to access information about the user profile, statistics, and results of previous measurements. This approach is justified, as it allows you to ensure both the protection of personal information of users and long-term reliable storage of this information. In the future, it will also allow organizing services with a paid subscription, which will ensure the provision of various services and services, as well as the storage and updating of the database of spectrogram standards for various substances.

To begin a molecular analysis, the NIR micro spectrometer is connected to the user's smartphone using Bluetooth 4.0 LE technology. This is necessary because the NIR spectrometer does not have a screen to display the results of the analysis, and is not able to independently process the primary data obtained during the molecular analysis. Therefore, during testing, it continuously transmits the results of molecular analysis to the smartphone, where they are intermediate accumulation and error control. This approach avoids sending incorrect information to the server, for example, when errors occur in the communication channel between the smartphone and the infrared micro spectrometer or false testing.

If the molecular analysis was successful and all the necessary primary data were transferred to the smartphone,

then from the smartphone they are sent over the Internet to the remote server of the developer. Primary molecular analysis data is processed on the server. Upon completion of the processing process, the results are transferred from the developer server to the user's smartphone for display in a user-friendly form.

In this case, the user's smartphone can be considered as a heterogeneous gateway, which provides the conversion of data transfer protocols in the transition between different types of networks, transmission control and pre-processing primary data [12].

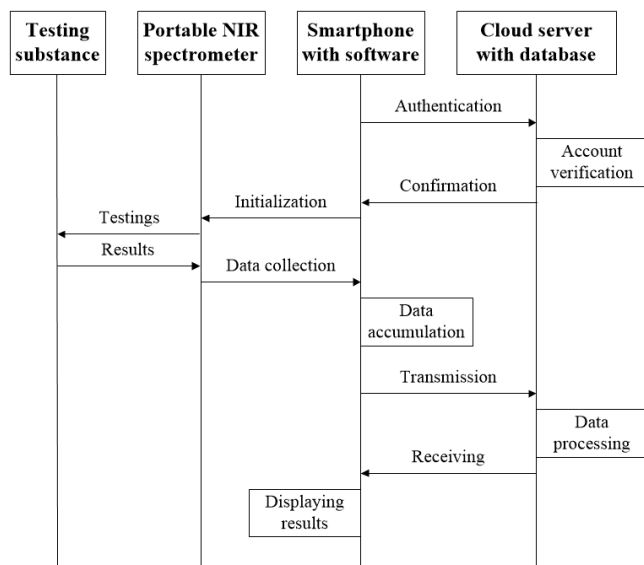


Figure 4. The process of collecting primary data, their transmission, processing and displaying the results of molecular analysis on the user's smartphone

V. TRAFFIC ANALYSIS

Next, we will intercept and study the traffic generated as a result of NIR spectroscopy. The interception will be performed on the user's smartphone with the Android operating system on two different interfaces. The interception of traffic on the Bluetooth interface will allow evaluating the characteristics of the traffic transmitted between the infrared microspectrometer and the user's smartphone. To do this, on the user's smartphone, we will enable recording in the log file of all data received/transmitted via the Bluetooth interface (Bluetooth HCI). Interception of traffic on the Wi-Fi interface will allow you to assess the characteristics of traffic transmitted between the smartphone and the remote server developers on the Internet. To do this, a Wicap traffic analyser software is installed on the user's smartphone. The final analysis of the recorded traffic will be performed using the Wireshark traffic analyser.

To study the characteristics of intercepted traffic, we construct an analytical model containing probabilistic distributions for the time intervals between sending packets (e.g. Figure 5) and processing packets (e.g. Figure 6).

Let's build the distribution of time intervals between sending packets.

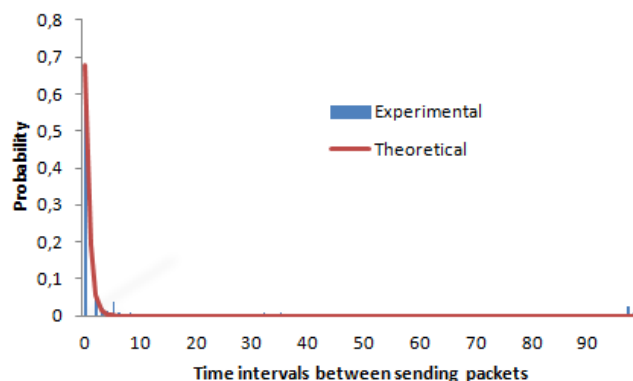


Figure 5. Distribution of time intervals between sending packets

The resulting distribution is an exponential distribution with $\lambda = 24.71$. Let's construct time intervals distribution of processing of packets.

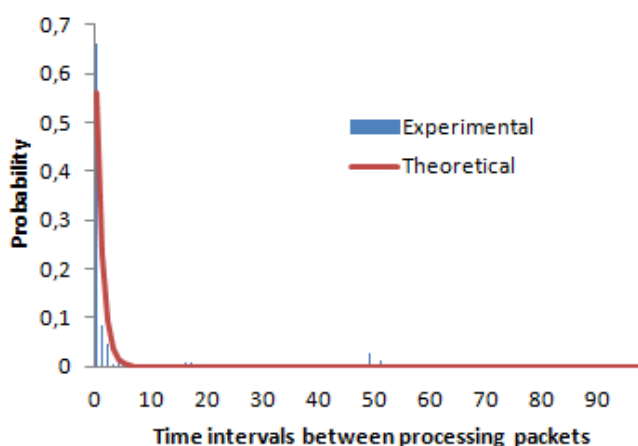


Figure 6. Distribution of packet processing time intervals

The resulting distribution is an exponential distribution with $\lambda = 8.94$ and offset $X_0 = 1.1 \text{ E-}05$. The final results are shown in Table 1.

TABLE 1. CHARACTERISTICS OF THE TRAFFIC

	Average value of time intervals, ms		Probability distribution	Kolmogorov-Smirnov test
	Practical	Theoretical		
Packet sending rate	$51,73 \pm 0,22$	$45,80 \pm 0,25$	Exponential ($\lambda = 24.71$, offset $X_0=0$)	$1,19 < 1,36$ (confirmed)
Packet processing rate	$147,82 \pm 0,61$	$134,35 \pm 0,60$	Exponential ($\lambda = 8.94$, offset $X_0=1.1 \text{ E-}05$)	$0,57 < 1,36$ (confirmed)

*Confidence probability of 95%.

According to the Kolmogorov-Smirnov test, the described probability distributions show a high degree of correspondence between the practical distribution obtained as a result of traffic interception and analysis and the analytical model [13].

VI. CONCLUSIONS

The present findings confirm according to the Kolmogorov-Smirnov test the described probability distributions show a high degree of correspondence between the practical distribution obtained as a result of traffic interception and analysis and the analytical model. The developed scheme of interaction of infrared micro spectrometer, smartphone and server on the Internet during molecular analysis and processing of its results is presented. The process of collecting primary data, their transmission, processing and displaying the results of molecular analysis on the user's smartphone is described.

Future research should be devoted to the development of more sophisticated and detailed analytical and mathematical models. In the future, when improving and developing the scheme of interaction of the infrared microspectrometer with other network devices, it is also necessary to take into account the potential trends in science and technology [14].

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Maxim Zakharov received the B.Sc., M.Sc. degrees from St. Petersburg State University of Telecommunications, Russia, in 2015, and 2017, respectively. He is currently an assistance lecturer with the Department of Telecommunication Networks and is studying in graduate school. From 2015 to 2019 he worked in the Internet of Things Laboratory at St. Petersburg State University of Telecommunication. His research areas include Internet of Things, software-defined networking, molecular networks and communications.



Ammar Muthanna received the B.Sc., M.Sc., and Ph.D. degrees from St. Petersburg State University of Telecommunications, Russia, in 2009, 2011, and 2016, respectively. In 2012 and 2013, he took part in the Erasmus Student Program with the Faculty of Electrical Engineering, University of Ljubljana. He is currently an Associate Professor with the Department of Telecommunication Networks, and also the Head of the SDN Laboratory, St. Petersburg State University of Telecommunications. His research areas include wireless communications, 4G/5G cellular systems, the IoT applications, and software-defined networking.



Dr. Sc. Ruslan Kirichek is working at the Bonch-Bruевич Saint Petersburg State University of Telecommunications as a Professor in the Department "Communication Networks and Data Transmission". He was born in 1982 in Tartu (Estonia). He graduated Military-Space Academy A.F. Mozhaiskogo and the Bonch-Bruевич St. Petersburg State University of Telecommunications in 2004 and 2007, respectively. He received Ph.D. at the Bonch-Bruевич St. Petersburg State University of Telecommunications in 2012 and Dr.Sc. at the Povolzhskiy State University of Telecommunications and Informatics in 2018. From 2008 to 2013 he worked as a senior researcher at the Federal State Unitary Enterprise "Center-Inform". Since 2012 he has been working as the Head of the Internet of Things Laboratory at the Bonch-Bruевич Saint Petersburg State University of Telecommunications (iotlab.ru). Since 2017 he has been working as ITU-T Q12/11 Rapporteur in "Testing of Internet of things, its applications and identification systems". He is a General Chair of the International Conference "Internet of Things and Its Enablers" (inithen.org).



Dr. Sc. Andrey Koucheryavy was born in Leningrad 02.02.1952. After graduated from the Leningrad University of Telecommunication in 1974, he went to Telecommunication Research Institute named LONIS, where he was working up to October 2003 (from 1986 up to 2003 as the First Deputy Director). He became the Ph.D. and Dr.Sc. in 1982 and 1994 respectively. He is at the Bonch-Bruевич St. Petersburg State University of Telecommunications (SUT) a professor from 1998. He is a Chaired professor of the department "Communication Networks and Data Transmission" from 2011. He is an honorary member of A.S.Popov's society. Prof. A.Koucheryavy is the Chairman of Study Group 11 ITU-T (Study periods 2017-2020). His scientific areas of interest are the network planning, teletraffic theory, IoT and its enablers.