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Meet the editor

Prof. Jaromir Gottvald in 2006 Vice Rector for Development and Social Affairs at VŠB-Technical University of Ostrava and since 2014 until September 2017 he had been the Vice Rector for International and Social Affairs at VŠB-TUO. Since 2007 Prof. Gottvald has been a Professor in National Economics and his main research interests include Applied Macroeconomics, Labour Market Economics, Wage determinants and Gender wage gap. He has been dealing with applied macroeconomics issues, particularly in the area of labour market economy. His latest research was related to the pay gaps between men and women at the Czech labour market, while the absolute wage difference amounted to one quarter in favour of men.

Prof. Petr Praus became university professor in Material Science and Engineering at VŠB-Technical University of Ostrava and since 2014 he has been the Vice Rector for Research and Development at VŠB-TUO. His main area of research interest includes synthesis and applications of nanomaterials including nanocomposites based on clay minerals. His research group has been investigating properties of various nanomaterials and nanoparticles of clay minerals and their possibilities for applications for a long time. Some clay minerals were used as carriers of synthetized nanoparticles forming nanocomposite materials and also were applied as absorbents for various compounds, such as cationic surfactants and heavy metal cations.

Contents

Section 1

Computational Sciences

Chapter 1

Traffic Management by Admission Control in IMS Networks

Ivan Baroňák, Michal Čuba, Chien-Ming Chen and Ladislav Beháň

Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/intechopen.71098

Abstract

The paper deals with traffic management in IP multimedia subsystem (IMS) networks. The aim of this article is ensuring quality of service (QoS) in IMS network. Admission control (AC) is used to manage incoming traffic and to prevent the network congestion. The main function of AC is to maximize the utilization of network resources and to ensure the level of QoS. AC was applied on constant bit rate (CBR) and variable bit rate (VBR) traffic. Three methods were chosen for VBR traffic and they were compared. The last part of the article deals with simulations CBR and VBR traffic before and after application of AC.

Keywords: admission control, CBR, IMS, VBR, QoS

1. Introduction

Nowadays, besides using basic services like telephony, SMS, and MMS, it is trend to link voice and data communication. IP multimedia subsystem (IMS) allows combining various multimedia services and access from mobile and fixed devices. Because of that, it seems to be the key element to achieve network convergence. The main advantage of IMS network is a guaranty of quality of service (QoS); this is especially important for real-time applications [1]. Admission control (AC) methods are used for that purpose [2].

2. Admission control

Admission control is a significant process from the point of view of ensuring of QoS [3]. The main function of AC is to estimate capacity for the incoming traffic. Additionally, it has to decide if it is possible to ensure this capacity without any negative impact on QoS of the existing traffic [4–7].

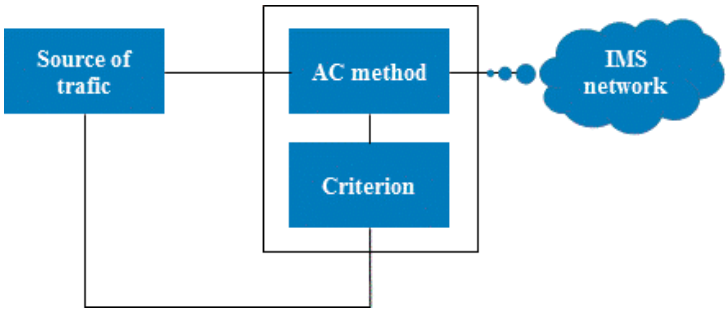

Figure 1. Management of incoming traffic by AC method.

It is a decision-making algorithm. It decides if a new connection is supposed to be allowed or denied within available network resources and guaranteed QoS [8–11].

The way how it works is shown in **Figure 1** [8]. If the new connection with a request of transmitting enters the node, the AC method determines a decisive criterion. The new connection is allowed or denied according to this criterion. The AC methods and specific algorithms are described in the next part. The admission control depends on type of source of traffic.

2.1. Constant bit rate (CBR)

The AC is a simple process in the case of constant bit rate traffic. Every source enters the node with constant bit rate, and it is simple to predict what capacity has to be allocated. Bit rate of every source is constant at the level of peak bit rate during connection. The AC has to keep the following condition:

$$\sum_{i=1}^{N} p_i + p_{i+1} \leq C, \tag{1}$$

where p_i is peak bit rate of ith connection, p_{i+1} is peak bit rate of new connection, N is number of existing connections, and C is a total capacity of output line, and it will be in all following equations [8].

2.2. Variable bit rate (VBR)

The AC is a complicated process in the case of variable bit rate traffic. The sources can transmit at the level of peak bit rate but also at the lower level. It would be ineffective to allocate the capacity at the level of peak bit rate for all connections. For reaching the maximal utilization of line capacity, the admission control methods, which are described in the next section, are used.

3. Admission control methods

Many admission control methods are known nowadays. They can be divided in general into measurement-based admission control (MBAC) and parameter-based admission control (PBAC). All of these methods are based on the following condition, which has to be respected:

$$P\left[\sum_{i=1}^{N} r_i(t) \geq C\right] < \varepsilon. \tag{2}$$

Probability that the sum of the immediate bit rate $r_i(t)$ of all N existing connections exceeds the total capacity C has to be lower than the defined bound ε [2, 3, 8, 9].

Good AC methods should keep these conditions:

- Keep QoS of the incoming connection without influencing other connections.
- To react and to decide within a short time to minimize the delay.
- Effectively allocate bandwidth to maximize utilization of the available capacity.

All of these methods should be simply implementable with the possibility of change and maintenance [8, 9].

3.1. Measured sum algorithm

This algorithm belongs among simple measurement-based methods. These methods acquire the necessary parameters by online measurement. The new connection is accepted according to the following condition:

$$C_m + r_{N+1} < \mu C, \tag{3}$$

where C_m is a measured load of the existing traffic; r_{N+1} is bit rate of the new connection; parameter μ expresses utilization of the line capacity from interval <0, 1>, in our case it is 0.95 (95%) and C is the total capacity of output line [12, 13].

3.2. Hoeffding bound

As it is mentioned in [12], the main parameter used by this method is the parameter of Hoeffding bound C_H, which is described by this equation:

$$C_H = v + \sqrt{\frac{\ln\left(\frac{1}{\varepsilon}\right) \sum_{i=1}^{N} (p_i)^2}{2}}, \tag{4}$$

where v is a measured average capacity, which is utilized by the existing connections; p_i is peak bit rate of ith connection; and N is a number of existing connections. According to this parameter, the method decides whether the new connection will be accepted or rejected. The new connection will be accepted according to the following condition:

$$C_H + p_{N+1} \leq \mu C, \tag{5}$$

where parameters μ and C are the same as in Eq. (3).

3.3. Peak rate allocation (PRA)

This method belongs to the group of nonstatistical methods. It is quite simple because it allocates the needed capacity at the level of peak bit rate for every connection. It does not depend on the fact, if the source transmits at the level of the peak bit rate or not.

The decision is made according to this condition:

$$\sum_{i=1}^{N} p_i + p_{N+1} < \mu C. \tag{6}$$

The new connection is accepted, if the sum of peak bit rates p_i of existing connections along with the peak bit rate of the new connection p_{N+1} is lower than the total capacity of the output line C.

The advantage of this method is that packet loss is very rare. The disadvantage of this method is that if sources do not transmit at the level of peak bit rate, the allocated capacity is not used effectively.

4. Simulations

The simulations were made in software Matlab. The scheme of the network node with AC is shown in **Figure 2**.

Every source represents user equipment. They create requirements using VBR or CBR. Requirements from users represent various data services. Sources are characterized by M × N matrix, where M is a number of sources and N is bit rates of these sources. The number of sources is 120,

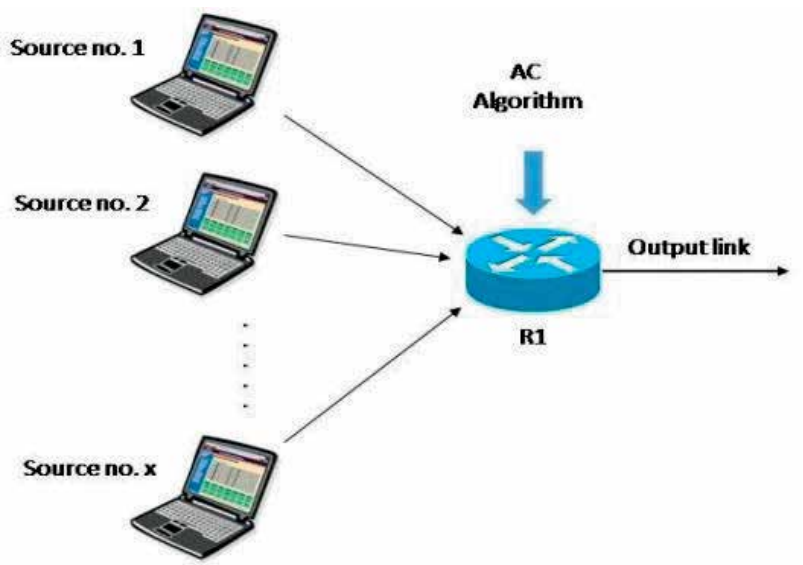

Figure 2. Network topology.

and they are connected to the node (router). There is one common line on its output with the capacity of 25 Mbit . s^{-1}. We consider the model that one user is connected by every second.

4.1. Constant bit rate (CBR)

In the case of the CBR, bit rates of sources are at the level of 250 kbit . s^{-1}. **Figure 3** shows when connecting of all sources would be allowed. As we can see, the capacity would be overloaded and QoS would be decreased.

This problem can be solved by using AC. In this case AC is a simple process. If condition (1) is accepted, the capacity will not be overloaded. Expected utilization of line using AC is shown in **Figure 4**.

Expected utilization of output line is under output capacity (red line). Maximum number of accepted connections is 95, and QoS is ensured for every source. This is achieved by admission control.

4.2. Variable bit rate (VBR)

In the case of the VBR, bit rates of sources are randomly generated from the interval from 0 to 512 kbit . s^{-1}. **Figure 5** shows expected utilization of the line, when all of the sources would be connected. As we can see in **Figure 5**, the capacity would be overloaded. That would cause packet loss or packet sequencing to the queue, and the delay would be increased. QoS of all connections would be negatively affected.

We are trying to prevent situations like that by using AC methods. If the connection of the new source causes a line overload, the connection request will be rejected.

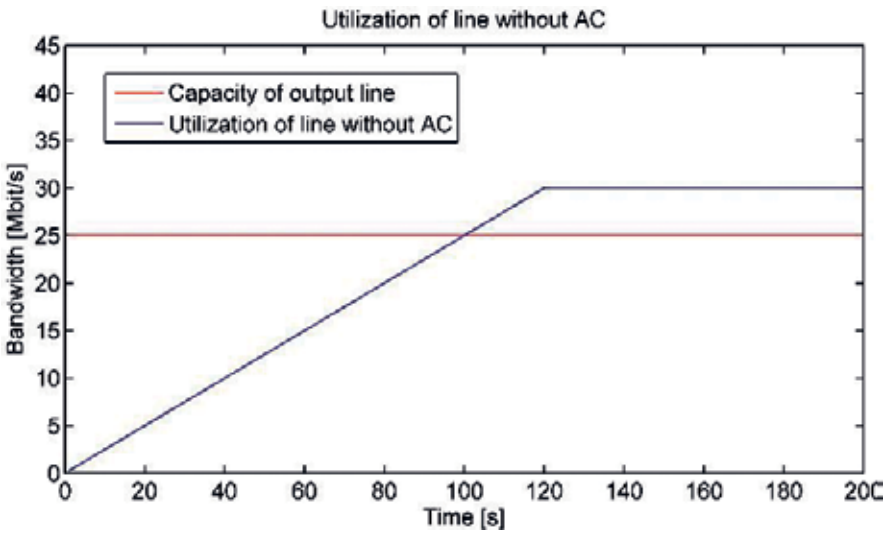

Figure 3. Expected utilization of line, when all sources are connected.

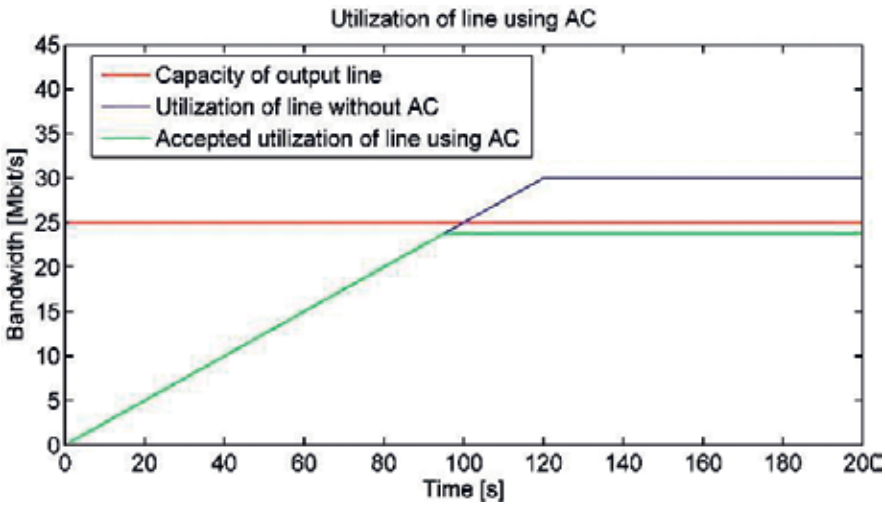

Figure 4. Accepted 95% utilization of line using AC.

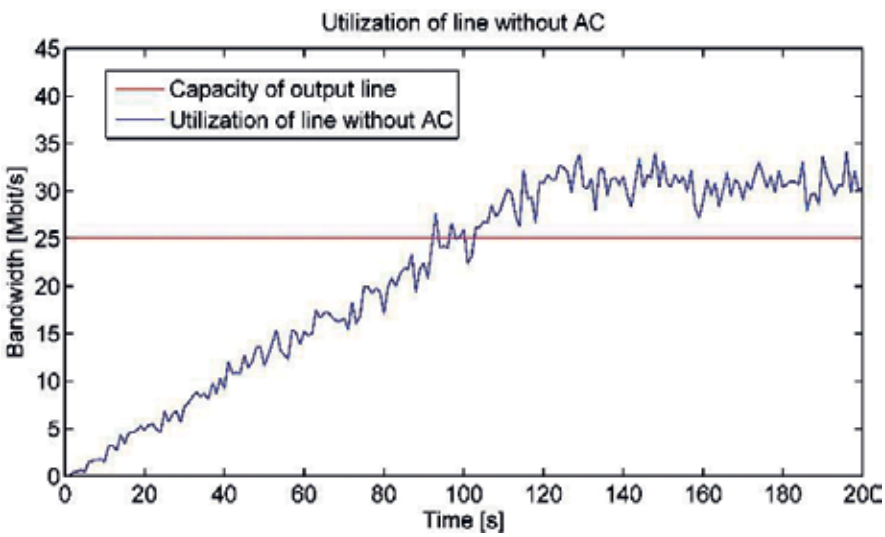

Figure 5. Expected utilization of line, when all sources are connected.

4.2.1. Measured sum

This method measures and sums bit rates of connected sources. The new connection is accepted or rejected due to the condition (3). **Figure 6** shows the accepted utilization of the line by the measured sum method.

It is obvious from **Figure 6** that when the method is applied, utilization of the line (green line) reaches the bound of the output capacity. The number of accepted connections is 90, which is the most of the compared simulated methods. The method maximizes utilization of the line

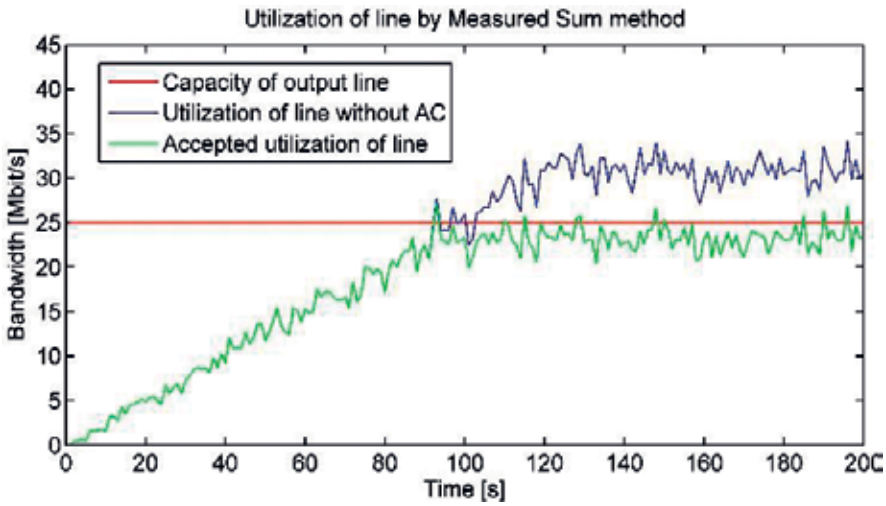

Figure 6. Accepted utilization of line by the measured sum method.

capacity. **Figure 6** shows that the output capacity can be overloaded in some points. The decision of the method depends on the immediate bit rates of the existing connections.

4.2.2. Peak rate allocation (PRA)

The new connection is accepted or rejected according to the condition (6). The accepted line utilization is shown in **Figure 7**.

In comparison with the measured sum method, the number of accepted connections is 46, which is half of the accepted connections by the measured sum method. PRA method is basically the

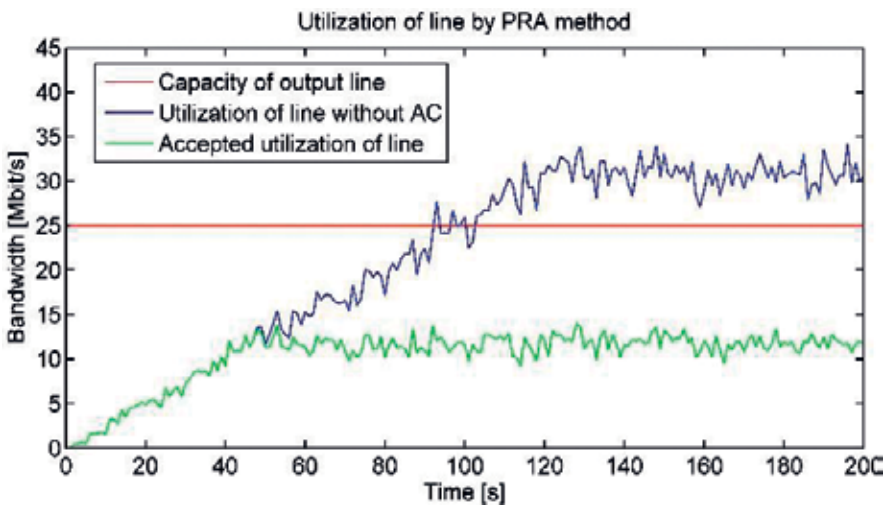

Figure 7. Accepted utilization of line by PRA method.

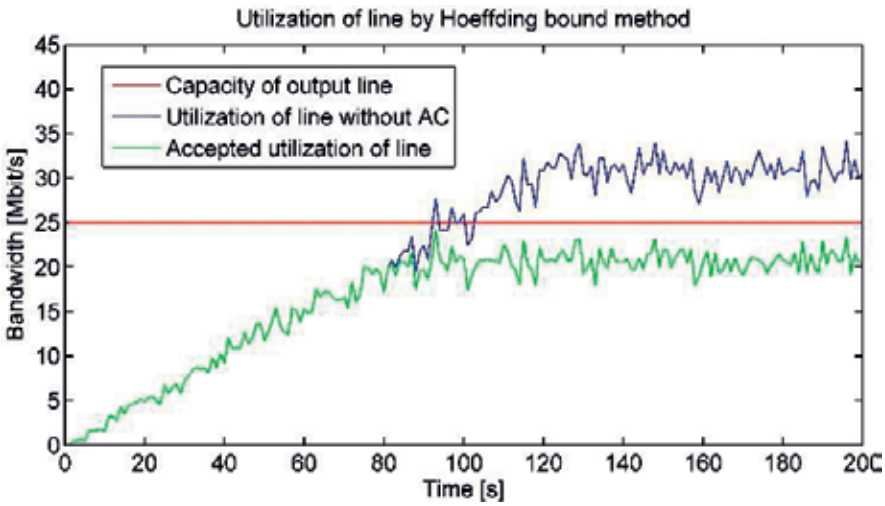

Figure 8. Accepted utilization of line by Hoeffding bound method.

opposite of the measured sum method [14]. It is caused by the fact that the PRA method allocates the capacity at the level of peak bit rate for every source. As we used VBR sources with randomly generated bit rates from the interval 0 to 512 kbit . s^{-1} with uniform distrubution, the average bit rate is at the level of half of the peak bit rate. Due to this, the capacity of the output line is not utilized effectively. The method is more appropriate for the CBR traffic or for the traffic where the bit rates are close to the peak bit rates. On the other hand, QoS of the existing connections would be decreased rarely.

4.2.3. Hoeffding bound

The Hoeffding bound is computed according to Eq. (4). The decision-making about accepting or rejecting the new connection is made according to the condition (5). The accepted utilization of the line is shown in **Figure 8**.

The specification of the decision-making criterion depends on an appropriate width of the measured interval. An interval, which is too small can cause a nonobjective decision-making. If we include all samples, computational difficulty would be very high [14, 15]. Dynamical sliding of the measured interval solved this problem. The number of accepted connections is 80, which is more than PBAC and PRA methods, but less than the measured sum method [16].

Figure 8 shows that overload of the capacity was minimized. This method seems to be the most appropriate one from all of the simulated methods. It is kind of a compromise between the number of accepted connections and the capacity overload of the output line.

5. VBR method comparison

The accepted utilization of line by every VBR simulated method is shown in **Figure 9**.

Table 1 shows the number of accepted connections by every method.

From **Figure 9** and **Table 1**, it is obvious that the most accepted connections were achieved by the measured sum method. On the other hand, this method has the most overloads of the output line capacity. It would cause a decreasing QoS. The second highest number of accepted connections is Hoeffding bound method. The overload capacity is minimal. Thanks to that this method seems to be the most appropriate one. The least accepted connections achieved the PRA method. It seems to be the least appropriate one for this kind of traffic.

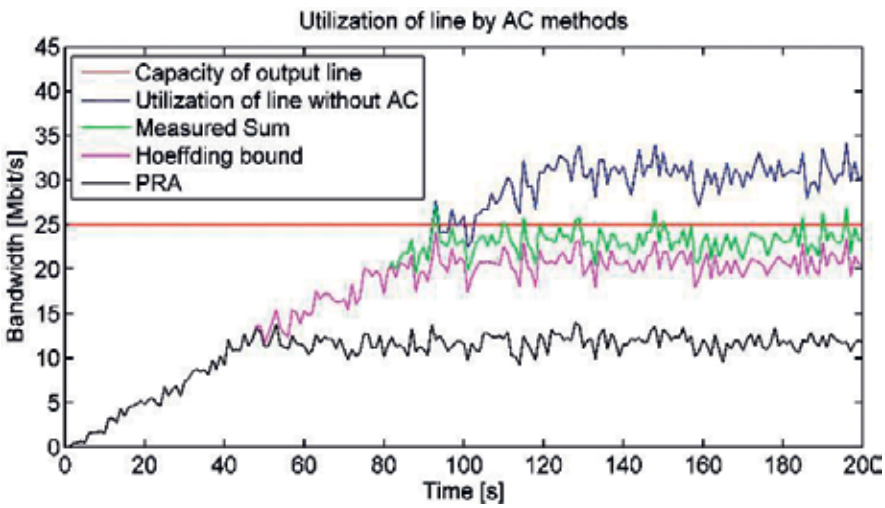

Figure 9. Accepted utilization of line by AC methods.

Method	Number of accepted connections
Measured sum	90
Hoeffding bound	80
PRA	46

Table 1. Number of accepted connections by every method.

6. Conclusion

Based on these results, we can claim that the AC methods are appropriate mechanisms for ensuring QoS in IMS networks. All known methods have the same function: to prevent overload and congestion. They have to decide whether the new connection will be accepted or rejected. From the simulations it is obvious that every method has advantages and disadvantages. The right choice of the method is very important for various specific kinds of traffic.

Acknowledgements

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Author details

Ivan Baroňák[1]*, Michal Čuba[1], Chien-Ming Chen[2] and Ladislav Beháň[3]

*Address all correspondence to: ivan.baronak@stuba.sk

1 Faculty of Electrical Engineering and Information Technology, Slovak University of Technology, Bratislava, Slovak Republic

2 School of Computer Science and Technology, Harbin Institute of Technology Shenzhen Graduate School, China

3 Faculty of Electrical Engineering and Computer Science, VŠB – Technical University of Ostrava, Ostrava, Czech Republic

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Chapter 2

Prepaid Voice Services Based on OpenBTS Platform

Ladislav Behan, Lukas Orcik, Filip Rezac,
Ivan Baronak and Jerry Chun Wei Lin

Additional information is available at the end of the chapter

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Abstract

This article describes the design and implementation of prepaid voice services based on OpenBTS platform. By using various programming languages and open-source software tools, we can integrate prepaid voice services with this system, so its functionality is resembled as much as possible the operation of traditional GSM network provider. This article also provides description of how customers will approach their billing services, how they will access their accounts and pay their invoices.

Keywords: GSM, OpenBTS, Asterisk, smqueue, Subscriber Registry, SIP, IAX, USRP, C++, PHP, trunk, VoIP

1. Introduction

Recently, GSM system is increasingly attracting the attention of the open-source community. Software implementation of the traditional GSM network would allow it to operate at much lower costs and would provide easier control over the entire system. The GSM network architecture is a remarkable piece of technology that many technicians developed for a very long time. It is very robust and also scalable but on the other side, quite inflexible and too expensive. Many open-source projects were built in order to address this. For example, Osmocom, OpenLTE, and YateBTS and Open Base Transceiver Station (OpenBTS) [1, 2]. Each project was built with different targets and architectures, tackling weak spots of traditional network in its own way.

Linux application OpenBTS (Open Base Transceiver Station) is one of the projects that allows user to create GSM network based on a software implementation. Due to economic software design and proper selection of powerful amplifiers, it allows user to install and operate a low-capacity GSM network at one-tenth of the cost of current technologies only. This project implements the GSM air interface (Um) that allows cellular handsets to be used as SIP endpoints. It provides Um interface by Universal Software Radio Peripheral (USRP) [3]. There are

still many areas on the Earth that do not have mobile network coverage or even telephone lines at home. But, they do have an Internet connection via satellite or long-haul WiFi. OpenBTS is able to convert and distribute this Internet connection as a mobile network across a large geographic region. This solution is suitable for building GSM in extreme conditions and the achieved PESQ quality [4] of such solution is presented in several papers [5, 6]. Any mobile phone connected to this network can transmit basic data, use voice services or send text messages. The combination of OpenBTS and USRP changes the way we should think about mobile networks. This technology allows user to build a complex radio network purely based on open-source software tools. OpenBTS is written in a C++ programming language and this application implements the whole GSM stack. OpenBTS is just a software. You can make it do whatever you would like, so OpenBTS network's capabilities can be enhanced with a non-difficult software update. The mobile network is finally open for innovation and anyone is able to build experimental cellular network now [7, 8].

There is no need for any configuration changes on the mobile stations, because the radio interface of OpenBTS network is equivalent to mentioned GSM network. The core of an OpenBTS network is composed of open protocols and IP is used as its transport protocol. Many software projects already exist and implement these open protocols, but there were some new components developed in order to provide a functionality to link the GSM and IP technology. Additionally, there are various applications providing efficient tools for the investigation of the GSM security issues [9–11].

The rest of this paper is organized as follows: In Section 2, the OpenBTS project is described in detail. Section 3 shows the design and implementation of accounting services integrated to our custom cellular network. Method of charging for voice is presented in Section 4. In Section 5, the application of control of exceeding the limit of prepaid services is presented. Section 6 describes how text messages are monitored in our network. Section 7 concludes the paper.

2. OpenBTS and its architecture

OpenBTS implements a complete GSM stack for voice, SMS and allows calls between registered mobile stations within created network and also between different network providers. These networks can be used to support true fixed-mobile convergence, bring coverage to remote areas or experiment and innovate within the cellular network itself. Because OpenBTS converts both cellular signaling and media directly to SIP [12] and RTP [13], the integration environment is quite familiar [14].

As mentioned earlier, OpenBTS itself is written in the programming language C++ and uses Asterisk PBX to place calls. Asterisk also allows this system to connect to various private or public IP networks. Mobile stations connected to OpenBTS network can reach each other even if the system is not connected to the Internet, but reaching someone outside the network requires an Internet connection. This new "hybrid" architecture is illustrated in **Figure 1** [15].

The crucial element of the whole OpenBTS architecture is a product of the Ettus Research, USRP. This is a relatively inexpensive hardware that is easily adaptable to GSM transmitter.

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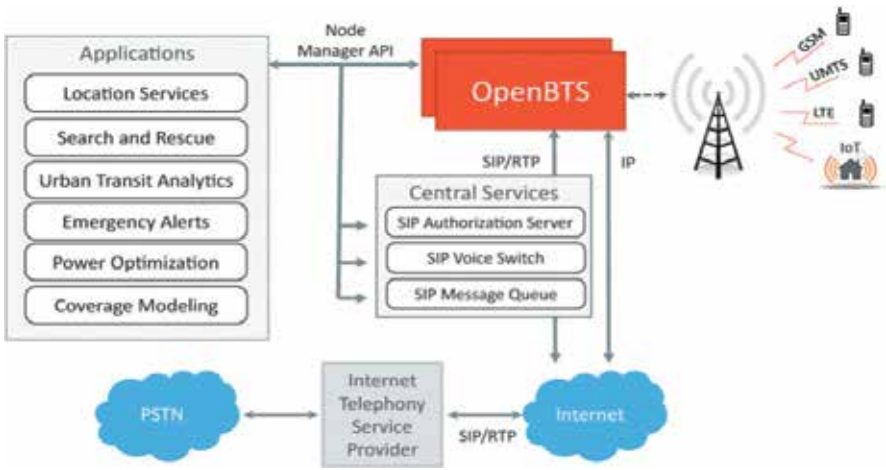

Figure 1. OpenBTS architecture [15].

USRP system consists of a motherboard which can be easily extended by the additional cards to provide and transmit signals with different frequency bands. It also consists of an USB interface, through which it communicates with the computer and a programmable FPGA. Motherboard contains A/D and D/A converters, processor interface and the controller power system to generate and synchronize clocks and FPGA. USRP needs UHD for a proper functionality. UHD is an open-source driver that is compatible with all operating systems and it is possible to use with LabView, GNU Radio or OpenBTS (**Figure 2**).

Sipauthserve is an application that implements Subscriber Registry, the database of subscriber information that takes place at both the Asterisk SIP registry and the GSM Home Location Register (HLR) that can be found in a conventional GSM network. The delivery of each text message in OpenBTS network depends on a store-and-forward facility. This facility is provided

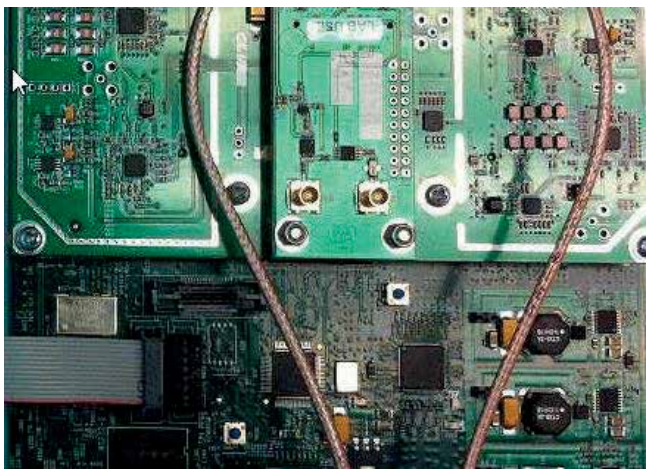

Figure 2. OpenBTS USRP N210 from Ettus Research [9].

by smqueue. The core of smqueue is a queue of messages that are waiting for delivery. They wait in this queue, potentially during multiple delivery attempts, until they are successfully delivered or until messages are determined to be undeliverable. The function of smqueue server is similar to email server [1].

3. Design and implementation of accounting services

Figure 3 shows connection scheme of OpenBTS network. Asterisk, OpenBTS, smqueue and sipauthserve are running on PC with the assigned IP address (158.196.229.242). A network switch connects PC, USRP N210 and IP phone together. In this topology, Asterisk is connected to two other Asterisk servers via IAX and SIP trunk. There are softphones connected to both of these servers.

Now we can connect any mobile station (MS) to our created network. If the connection was successfully established, the IMSI number of the phone SIM card is stored in the TMSITable database. We created a C++ program that continuously checks this database for a new IMSI records. If the new IMSI appears, then this program will check whether the record exists in sip_buddies table. If sip_buddies table does not contain this IMSI number, then program will generate a phone number, inserts a record to this sqlite3 database and modifies the configuration files of Asterisk.

As you can see in **Figure 4**, if MS successfully connects to OpenBTS network, it will obtain a welcome message with information about its generated phone number and IMSI number. With these numbers user is able to login onto his account at the service provider's website where he should activate voice services. Every generated phone number or IMSI number is unique so there is no possibility to duplicate a data. After user's successful logging, the welcome page should appear with a main menu where user can choose from following items: Services, Statistics, Summary and Contact. After opening the Services tab, users are offered to be able to activate various services. They are able to choose either one of the credit services or activate one of the fixed payment tariffs (**Figure 5**).

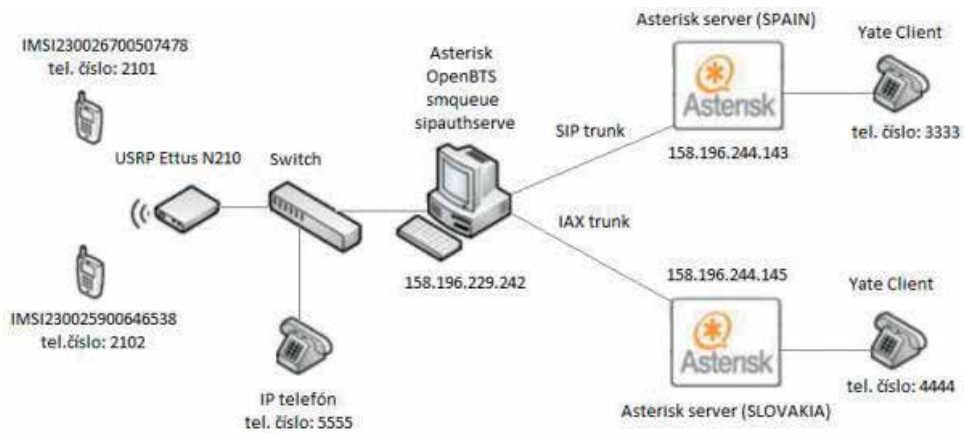

Figure 3. Connection scheme of OpenBTS network.

```
INFO:    Searching for new IMSI...
SUCCESS: New IMSI found =>IMSI230024701231666 !!!
INFO:    Opening database...OK
INFO:    IMSI not used, creating new record.
INFO:    Inserting to db: id(2), number(2101), imsi(IMSI230024701231666)
SUCCESS: Inserting to dialdata_table...OK
SUCCESS: Inserting to SIP_BUDDIES...OK
SUCCESS: /etc/asterisk/sip.conf updated.
SUCCESS: /etc/asterisk/extensions.conf updated.
INFO:    Closing DB...OK
INFO:    Welcome message was successfully sent !!

INFO:    Searching for new IMSI...
```

Figure 4. Automatic IMSI registration in OpenBTS network.

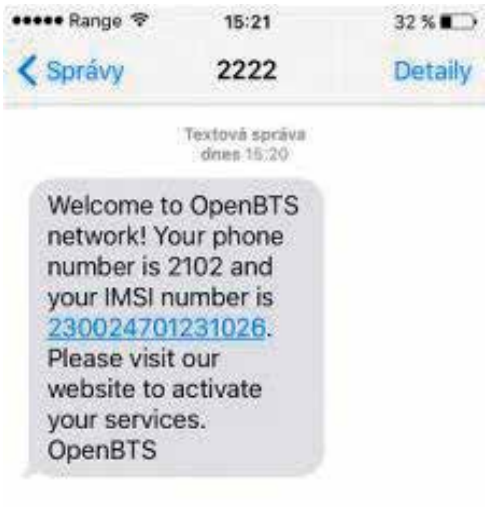

Figure 5. OpenBTS welcome message.

Each button containing a prepaid voice service is connected to the PayPal Internet-based payment system. After choosing preferred service, user will be redirected to PayPal website, where he will be asked to pay the amount for the specific tariff. In the Summary tab, see **Figure 6**, there is possibility to review all calls that have been made retrospectively. This table shows to which extensions user was calling and to which network area this number belongs. Then he can view the total duration of the call with exact start and end time of the call. Last item is showing the amount charged for this call. User is also able to download this entire summary report as a PDF file. Files are created by the FPDF tool that is a PHP class which allows to generate PDF files.

The Statistics tab consists of individual statistics. For example, as we can see in **Figure 7**, the user is able to view the number of calls he made in each month. The number of text messages he sent is shown in **Figure 8** and the total amount of money paid for voice services is shown in **Figure 9**. These graphs are generated by object-oriented PHP library JPGraph that is processing user's data retrieved from a SQL database.

OpenBTS telefónica

SUMMARY OF CALLS

Id	User	Country	Called	Start	End	Duration (sec)	Price(CZK)
1	2101	CzechRep	2102	16:51:14	16:52:22	8	4
2	2101	CzechRep	2102	16:53:28	16:54:20	52	26
3	2101	SPAIN	3333	17:00:18	17:00:56	38	38
4	2101	SPAIN	3333	17:02:16	17:02:48	32	16
5	2101	SPAIN	3333	17:05:01	17:06:23	82	41
6	2101	IPPHONE	5555	14:25:31	14:26:17	46	35
7	2101	IPPHONE	5555	18:41:12	18:43:11	59	44
8	2101	SLOVAKIA	4444	20:21:33	20:22:49	76	152

Figure 6. Summary of calls table.

Figure 7. Number of calls made per month.

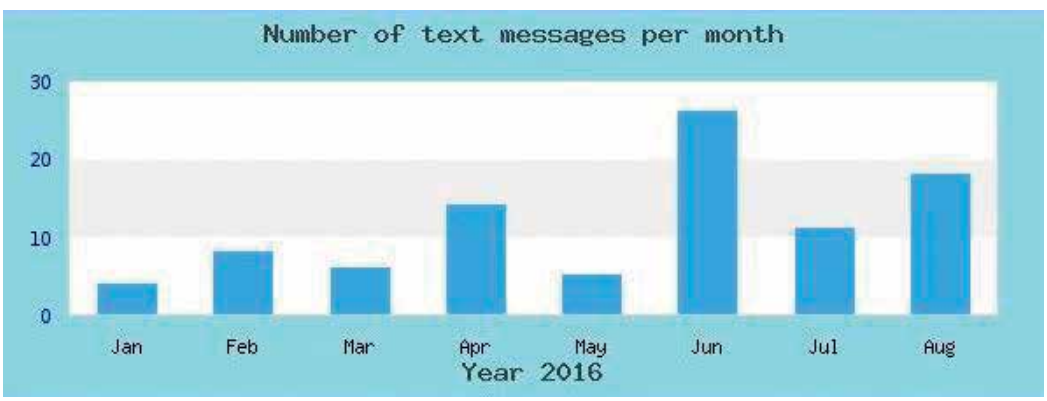

Figure 8. Number of text messages sent per month.

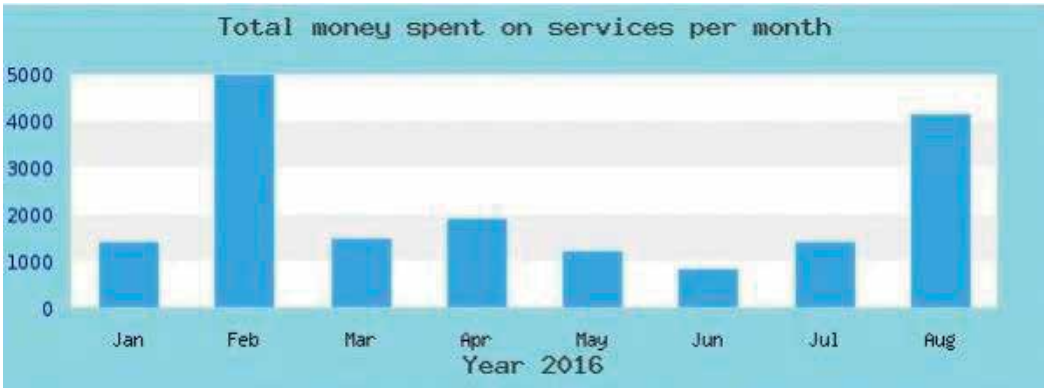

Figure 9. Total money spent on service per month.

4. Method of charging for voice services in the OpenBTS network

Phone calls in OpenBTS network are routed via the Asterisk PBX that stores detailed records related to these calls in the Master.csv file. Asterisk stores these calling data records (CDR) to this csv file after every call is processed. CDR records consist of very important data for our billing system implementation. For example, the phone number of the subscriber originating the call, the phone number receiving the call, the call duration or the starting time of the call (date and time).

We implemented a C++ application that parses these CDR records from Master.csv file and stores them to various databases used in our billing system. This application is continuously checking Master.csv file for a new record. If a new CDR record has been added, application

```
SUCCESS: SQLITE DB was successfully OPENED!
SUCCESS: Username found in DB!
INFO   : The call lasted : 68 seconds
INFO   : User -> 2101 has service -> cash
INFO   : Updating credit status...
INFO   : Call was made in Czech Republic, prize -> 34 CZK
INFO   : Updating users table...
SUCCESS: SQLITE DB was successfully UPDATED!
SUCCESS: MYSQL DB was successfully OPENED!
SUCCESS: MYSQL DB was successfully UPDATED!
SUCCESS: MYSQL DB was successfully CLOSED!
SUCCESS: MYSQL DB was successfully OPENED!
SUCCESS: MYSQL DB call data successfully INSERTED!
SUCCESS: MYSQL DB number of calls was UPDATED!
SUCCESS: SQLITE DB was successfully CLOSED!
```

Figure 10. Program flow of cdr_manager.Cpp.

will find out what is the user's activated service. If he has activated one of the tariff services, then the total call time will be subtracted from the rest of his free prepaid minutes. If he has activated the credit service then the resulting sum of the call will be calculated in accordance of where the call was routed (IP phone, SIP/IAX trunk, MS). **Figure 10** shows the flow of cdr_manager application when the new CDR record has been found.

Figure 11 shows that application also checks if the user's credit balance is not too low. If it finds out the remaining credit is under 20 CZK then it will send a notification message to him.

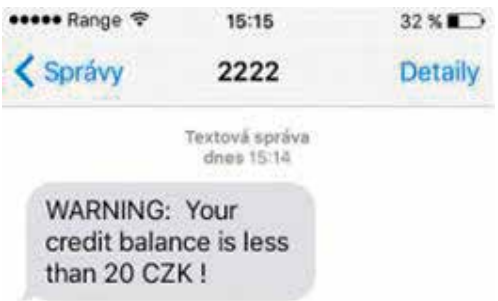

Figure 11. Low credit balance message.

5. Control of exceeding the limit of prepaid services

Another essential part of our billing system is to check if the caller did not exceed his limit of prepaid services during the active phone call. We implemented an application call_manager.cpp that constantly monitors occupancy of Asterisk PBX channels. **Figure 12** shows the flow of this application.

As we have mentioned, the whole process starts with constantly enquiring Asterisk about the state of the call channels. If Asterisk confirms that there has been an active channel found, the call_manager checks if a caller extension has its prepaid service active. If not, the

```
SUCCESS: Database was successfully opened!
SUCCESS: Active channel found!!
INFO   : Active channel is used by -> 2101 <=> 2102
INFO   : 2101 has service -> cash
INFO   : User 2101 is allowed to use this channel for 60 secs
INFO   : Allowed time was exceeded -> terminating active channel!!!
INFO   : Text message was sent to user!
INFO   : Updating credit status for user: 2101
SUCCESS: Updating database..OK!
INFO   : User -> 2101 don't have enough money to make a call!!!
```

Figure 12. Call_manager.cpp flow.

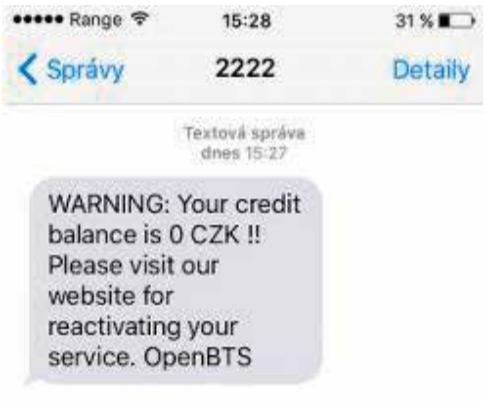

Figure 13. Zero credit text message.

application will terminate this channel immediately and the following text message is send to MS (**Figure 13**).

If the user's account is non-zero then the application will determine whether the call will be routed through SIP/IAX trunk, IP Phone or call will be made on the OpenBTS network. Based on that data our application will determine the time for how long is the caller able to use the voice channel.

In cases when the time limit has exceeded, the voice channel will be terminated immediately, the program opens a database containing information about the caller's prepaid services and set them to zero. At that point, the user will be informed about the zero balance of his account via SMS. He is also invited to visit the service provider's website to reactivate his service, otherwise he will not be able to make calls or send any text messages.

6. Text message billing

Another important part of our billing system is a way to monitor sent text messages. In this case, we implemented application that is parsing messages stored in OpenBTS.log file. This program regularly monitors mentioned file and select only messages with specific content like the following example:

Mar 2 15:03:22 studentPC smqueue: NOTICE 4842:4848 2016-03-02 T15:03:22.1 smqueue.cpp:2455: main_loop: Got SMS rqst qtag '658,054– OBTSbwgdfkphscqborwe' from IMSI230024701231026 $.

The other application sms_manager.cpp then parses this message and picks information about IMSI number. According to this IMSI number, program checks the user's service and its status. If he has activated one of the tariff services then the total free text messages is subtracted by 1, in case of a credit service there is a fee charged for this text message. The program then updates the database that indicates the number of messages sent per month.

```
INFO   : User with imsi number IMSI230024701231026 sent sms!
SUCCESS: SQLITE DB was successfully OPENED!
INFO   : His phone number is -> 2101
INFO   : Updating SQlite table...
SUCCESS: SQLITE DB was successfully UPDATED!
INFO   : Updating MySQL table...
SUCCESS: MYSQL DB number of text messages was successfully UPDATED!
```

Figure 14. Sms_manager.cpp flow.

As mentioned earlier, these statistics are then graphically available on the service provider website (**Figure 14**).

7. Conclusion

In this article, we demonstrated the possibility of creating a billing system working correctly in conjunction with the OpenBTS platform and providing an important part of the mobile operator system based on OpenBTS. First of all, we automate the registration of IMSI numbers, which means that after the phone is registered to the network, the phone number is automatically assigned to it. This author's contribution in community of OpenBTS project. Using various software tools and programming languages, we have implemented our own billing system that we integrated to OpenBTS system and it led to low-cost mobile operator creation. Last that is missing to completeness is data service integration that can be provided by integrating OsmoSGSN a OpenGGSN nodes to our system. OpenBTS system proves that nearly anyone can run a custom GSM network with parts from a home-supply or auto-supply store. The technology required to build this kind of network is no longer far too expensive, nor has a fistful of big companies locked them down. Mobile phone users within this network are able to make calls to each other and if the network is connected to the Internet, they can make calls to people around the world.

Contribution of this paper lies in an experimental development of the solution for mobile operators which is based on the OpenBTS platform with widely available USRP HW and SW tools implemented within this experimental research. The solution can be operated in areas, where mobile operators do not cover, and no mobile infrastructure exists, especially on islands.

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Author details

Ladislav Behan[1]*, Lukas Orcik[1], Filip Rezac[2], Ivan Baronak[2] and Jerry Chun Wei Lin[3]

*Address all correspondence to: ladislav.behan@vsb.cz

1 Faculty of Electrical Engineering and Computer Science, VSB—Technical University of Ostrava, Ostrava, Czech Republic

2 Faculty of Electrical Engineering and Information Technology, Slovak University of Technology, Bratislava, Slovak Republic

3 School of Computer Science and Technology, Harbin Institute of Technology Shenzhen Graduate School, Shenzhen, Guangdong, China

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Chapter 3

Study of Admission Control Methods for IPTV Services

Erik Chromy, Tsu-Yang Wu, Roman Cipov, Matej Kavacky, Stanislav Klucik, Ivan Baronak and Lukas Orcik

Additional information is available at the end of the chapter

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Abstract

The paper deals with admission control methods used in Internet Protocol (IP) Multimedia Subsystem. The purpose of implementing AC methods in IP Multimedia Subsystem (IMS) is to control the access of incoming connections to network resources. At the Institute of Telecommunications, we have built an experimental laboratory, which is used to test these methods. In this paper, we focus on Internet Protocol Television (IPTV) services; therefore, we have created a variable bit-rate IPTV traffic generator that is used as the input to the network, so we can test the behavior of selected AC methods. They are implemented in a simulated IPTV service provider access network, so we can examine the effects of variable bit-rate IPTV streams on the decisions made by those methods. To calculate the required bandwidth of an input stream, two simulation scenarios with different number of input packets were performed. One of these AC methods was modified where the peak input rate parameter of an IPTV stream was replaced by the average bit-rate of this stream. At the end of this paper, we discuss the achieved results.

Keywords: admission control, IP Multimedia Subsystem, IPTV

1. Introduction

The usage of admission control (AC) methods in connection-oriented network is well known (e.g. CAC methods in ATM networks). But there is also a need to study AC methods in connectionless networks. The Resource and Admission Control Sub-system (RACS) block in an IMS network [1, 2] is responsible for admission and resource control. The functional architecture of RACS block is described in the standard document ETSI ES 282 003 v1.1.1. It is one of the most important blocks of the IMS architecture, and it decides whether a service or connection will be accepted or rejected. The document itself or the available scientific literature does not mention which admission control method or algorithm should be implemented in the RACS block.

The main task of AC methods is to provide sufficient bandwidth for each user service so that required Quality of Service (QoS) [3, 4] will be ensured. AC methods are defined within an IMS network node through the users who are accessing services.

A decision rule is the important part of an AC method. Whether a new request to the network will be accepted depends on the ability of the AC method to retain the QoS for both, existing services [5–7] and the new service that requests additional network resources.

Various methods for Quality of Service rating are used, e.g. subjective or objective. Subjective methods are based on feelings of users during the service provision. For admission control methods, we need to define objective parameters. The main goal of telecommunication operators is to ensure QoS parameters [8, 9] on required levels together with effective bandwidth utilization. The admission control takes a key role in service provisioning (VoIP, IPTV). A wrong AC decision can inflict degradation of QoS parameters for existing [10–12] and for newly accepted data flows.

The key feature of every AC method is the ability to precisely estimate the required bandwidth of an incoming data flow. This estimation is usually based on a theoretical analysis of the network traffic and its accuracy is limited by various simplifications that are used. For example, such a simplification is the use of constant packet lengths or constant times between consecutive packets within a stream [13]. There are many admission control methods and they can be classified into two groups:

- Parameter-based admission control (PBAC) methods and
- Measurement-based admission control (MBAC) methods.

In these papers [14, 15], various methods and algorithms for admission control have been proposed.

2. Simulation model

The purpose of our simulations is to verify the proposed IPTV traffic generator and to identify suitable AC method for IPTV services. Simulations were realized in the MATLAB environment. Input data flows were generated using the IPTV generator defined in [16]. The principle of simulations is depicted in **Figure 1**.

The users generate requests for IPTV streams that are received in the network node (router) which uses a defined AC method. Only one request from one user can originate at a time. At the beginning of the simulation, there were no users connected into the test network. If any connection request is rejected by admission control method, then every new connection request is also rejected.

2.1. Simulation principles

For simulation purpose, we need to convert packet departure times into transmission rate of IPTV flows. For this conversion, we need to know the packet size and number of packets sent per defined time interval. The ratio of these two values gives transmission rate. For conversion,

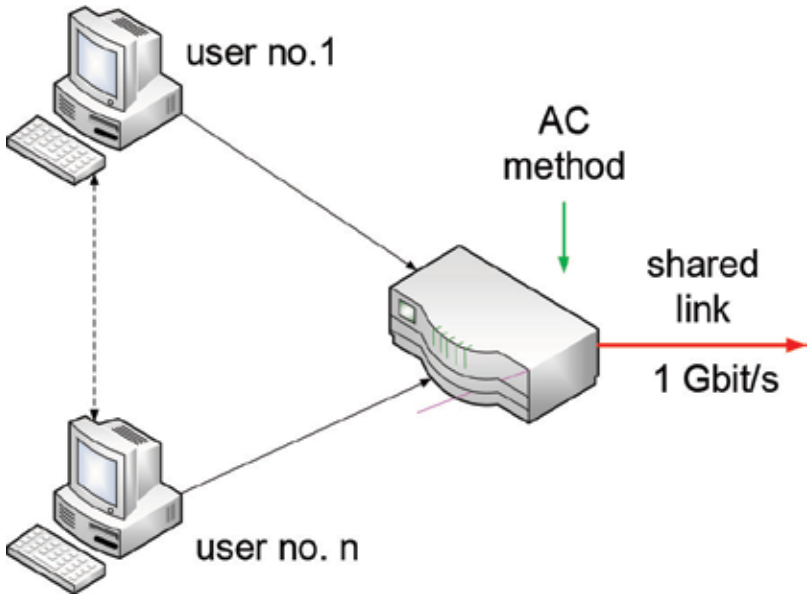

Figure 1. Network topology used for simulations.

it is important to know how frequently the router calculates the parameters of data flows. In our simulations, we used two versions of conversion—conversion for every 1000 packets (*version A*) and for every 100 packets (*version B*). It means conversion of transmission rate around every 2 ms for *version A* and 10 times more frequently for *version B*. Such frequent conversion helps to catch amplitudes (i.e. minimum and maximum) characteristic for variable bit rate traffic. The transmission rates were calculated for IPTV flows for both versions (*A* and *B*) from output of above described generator. Two matrices were created. The rows in the matrix represent IPTV flows and their transmission rates in particular time moments. Parameters of IPTV flow are the minimal transmission rate: 3.51 Mbps, the maximal transmission rate: 14.59 Mbps, and the average transmission rate: 6.14 Mbps.

Four simulations of AC methods were performed—*Measured Sum*, *Hoeffding Bound*, and two versions of *Acceptance Region* method. These methods were implemented in the router depicted in **Figure 1**. IPTV flows share common link with transmission capacity of 1 Gbps (it is the value of parameter *B* for all implemented methods in simulations). For parameter *u*, i.e. percentage utilization of bandwidth, the value 0.98 (i.e. 98%) was used.

3. Simulations

The following simulation parameters were observed and evaluated:

- Number of accepted connections
- Average link utilization (%)
- Loss (%).

Each method was evaluated for both versions of transmission rate conversion of input data flows—transmission rate conversion for every 1000 packets (*version A*) and for every 100 packets (*version B*).

If any connection request is rejected by admission control method, then every new connection request is also rejected. From that moment (in the graphs depicted by vertical black line), the observed parameters are evaluated.

3.1. Simulation of *Measured Sum* method

Acceptance of a new requesting connection into the network is based on Eq. (1):

$$v + r \leq uB \tag{1}$$

where v represents used bandwidth for existing connections, r is required bandwidth for new connection, B is overall link capacity, and u is percentage utilization of bandwidth (**Table 1**).

The resulting data flows for version A are depicted in **Figure 2**.

Version	Accepted connections	Link utilization (%)	Loss (%)
A	155	95.42	0.25634
B	141	91.83	0.704579

Table 1. Simulation results of *Measured Sum method*.

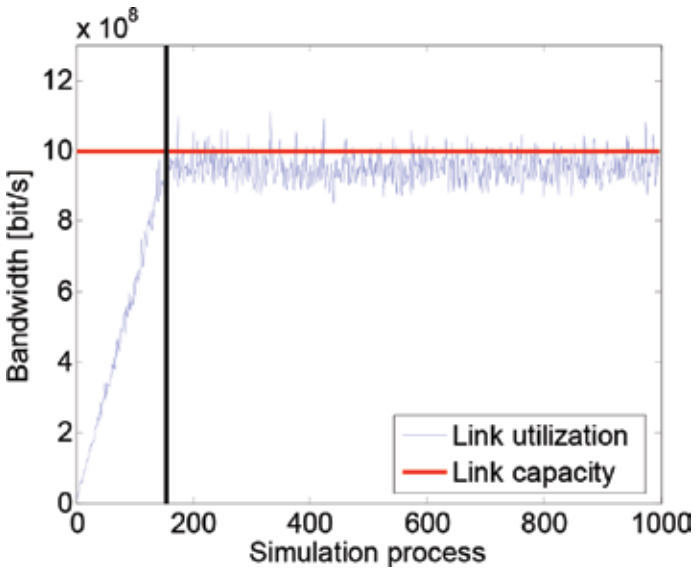

Figure 2. Simulation of *Measured Sum method*—version A.

3.2. Simulation of *Hoeffding Bound* method

Acceptance of the new requesting connection into the network is based on Eq. (2):

$$C_H + p \leq uB \tag{2}$$

For parameter p, the current bandwidth of the requesting connection is used, for parameter p_i in Eq. (3):

$$C_H = v + \sqrt{\frac{ln\left(\frac{1}{\varepsilon}\right)\sum_{i=1}^{n}\left(p_i\right)^2}{2}} \tag{3}$$

are current bandwidths of already accepted connections in the given time moment. Parameter ε (probability that requesting connection will exceed link capacity) was set to 0.05 (i.e. 5%). Resulting data flows for version A are depicted in **Figure 3** (**Table 2**).

3.3. Simulation of *Acceptance Region* method—variant 1

Acceptance of the new requesting connection into the network is based on Eq. (4):

$$np(1 - e^{-sp}) + e^{-sp}v \leq uB \tag{4}$$

Parameter s was set to the value 10^{-8}. Parameter p denotes the peak bandwidth of the requesting connection. This value is obtained as a maximum value of first 100 values of the transmission rate of the IPTV flow. This value respects two aspects—sufficient number of patterns for representation of data flow and acceptable contribution to delay (and related preservation of computation simplicity). Parameter n represents the number of accepted flows. Therefore, the implementation of buffer for the first 100 values of transmission rate of

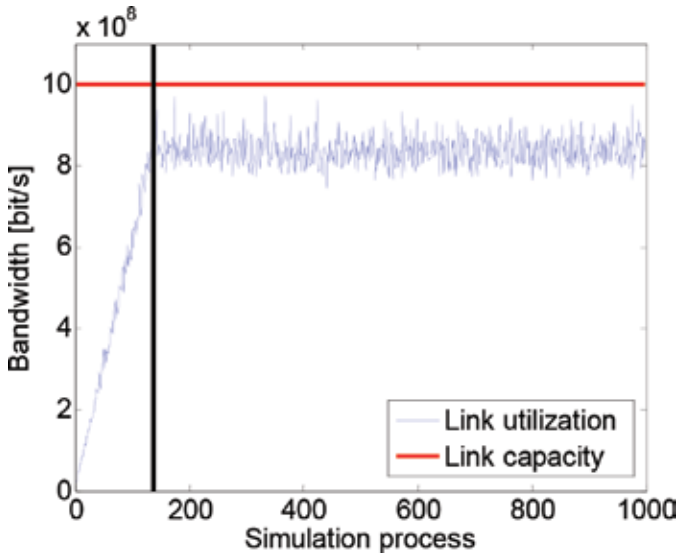

Figure 3. Simulation of *Hoeffding Bound* method—version A.

requesting connection is needed for this method. The value of parameter p is then equal to maximum value of this array of values. Resulting data flows for version A are depicted in **Figure 4** (**Table 3**).

Version	Accepted connections	Link utilization (%)	Loss (%)
A	137	83.83	0
B	125	80.78	0.0238593

Table 2. Simulation results of *Hoeffding Bound method*.

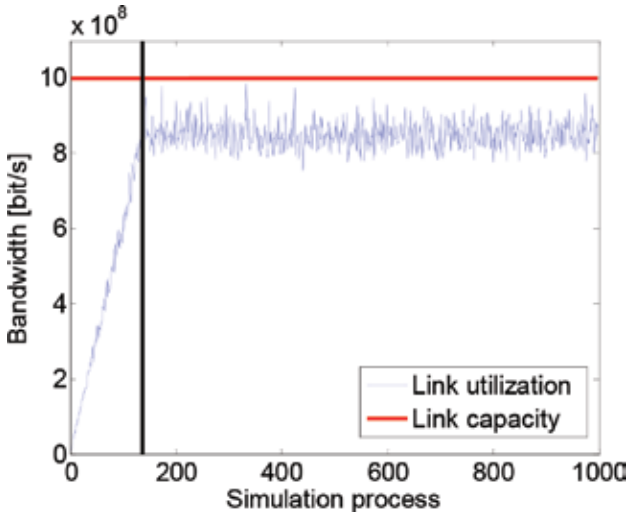

Figure 4. Simulation of *Acceptance Region method*—variant 1 (version A).

Version	Accepted connections	Link utilization (%)	Loss (%)
A	138	85.02	0
B	126	82.81	0.03564

Table 3. Simulation results of *Acceptance Region method*—variant 1.

3.4. Simulation of *Acceptance Region* method—variant 2

Acceptance of a new requesting connection into the network is based on Eq. (5):

$$e^{sp}v \leq uB \tag{5}$$

For this method, two simulations were performed. For the first simulation, the theoretically described parameters were used. For the second simulation, the calculation of parameter p was changed. The same buffer is used as in previous case, but the value of parameter p is the mean value of the first 100 values of transmission rate of the requesting connection (**Table 4**).

Version	Accepted connections	Link utilization (%)	Loss (%)
A	137	83.83	0
A *modified*	138	85.02	0
B	124	80.78	0.023832
B *modified*	135	87.91	0.247054

Table 4. Simulation results of original and modified *Acceptance Region method*—variant 2.

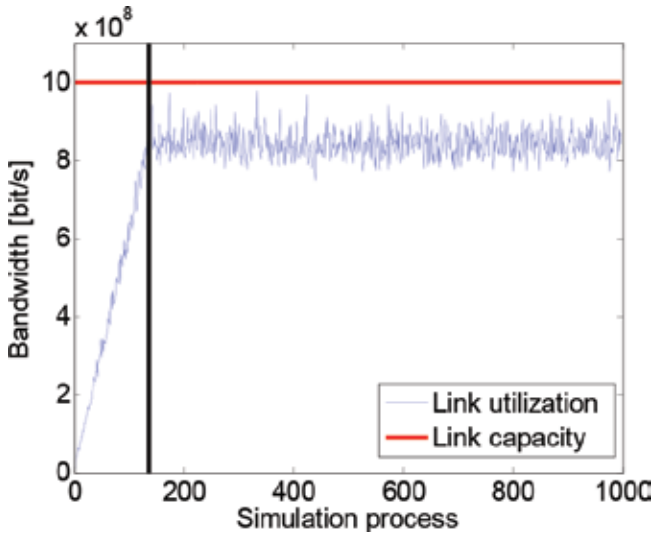

Figure 5. Simulation of *Acceptance Region method*—variant 2 (version A).

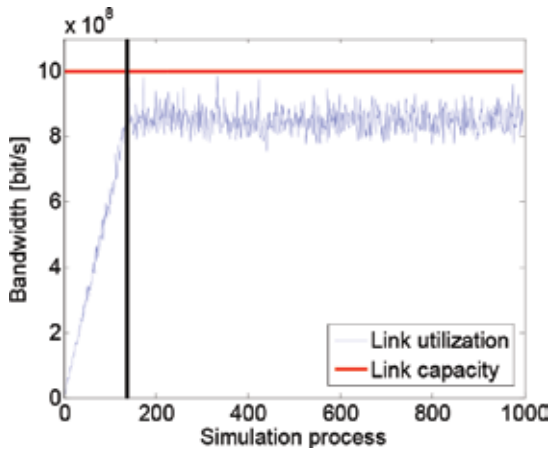

Figure 6. Simulation of modified *Acceptance Region method*—variant 2 (version A).

At first glance, it is a small change, but the simulation results are different. The version *A* of this method accepted one more connection after this change (while zero losses were preserved). The version *B* of the modified method accepted about 11 connections more. But it has a great impact on loss, which is too high, and recommended value for IPTV QoS is not fulfilled. Resulting data flows for version *A* of original method are depicted in **Figure 5** and for modified method in **Figure 6**.

4. Evaluation and comparison of simulation results

Simulation results are stated in **Table 5**. It is proven that the number of accepted connections into the network together with evaluation of link parameters depends on the conversion interval of parameters of input data flows. Obtained results of parameters for *version A* (conversion of transmission rate for every 1000 packets) and *version B* (conversion of transmission rate for every 100 packets) of the same method considerably differ.

Based on the simulation results, we can suggest *Acceptance Region* method—variant 1 as the most suitable AC method for IPTV services. This method is the most suitable regardless of conversion of transmission rates in routers for every 100 or 1000 received packets. By using this method, we can maximize the bandwidth utilization together with guarantee of the requested quality of service.

AC method	Version	Accepted connections	Link utilization (%)	Loss (%)
Measured Sum	A	155	95.42	0.25634
Measured Sum	B	141	91.83	0.704579
Hoeffding Bound	A	137	83.83	0
Hoeffding Bound	B	125	80.78	0.0238593
Acceptance Region—variant 1	A	138	85.02	0
Acceptance Region—variant 1	B	126	82.81	0.03564
Acceptance Region—variant 2	A	137	83.83	0
Acceptance Region modified—variant 2	A	138	85.02	0
Acceptance Region—variant 2	B	124	80.78	0.023832
Acceptance Region modified—variant 2	B	135	87.91	0.247054

Table 5. Simulation results of AC methods and their comparison.

5. Conclusion

The paper deals with admission control methods in IMS networks. We have simulated four admission control methods—*Measured Sum*, *Hoeffding Bound*, and *Acceptance Region* (two

variants). In addition, the modification of *Acceptance Region* method for variant 2 was performed. The modification replaces the peak bandwidth value with the average bandwidth value. Based on performed simulations, we identified the Acceptance bound method—variant 1 as the most suitable AC method for IPTV services.

In the future work on our experimental IMS laboratory, we intend to implement selected admission control methods into the access part of the IMS network architecture. Then, we will evaluate implemented method in real time for IPTV services.

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Author details

Erik Chromy[1]*, Tsu-Yang Wu[2], Roman Cipov[1], Matej Kavacky[1], Stanislav Klucik[1], Ivan Baronak[1] and Lukas Orcik[3]

*Address all correspondence to: chromy@ut.fei.stuba.sk

1 Institute of Telecommunications, Slovak University of Technology in Bratislava, Bratislava, Slovakia

2 Fujian Provincial Key Laboratory of Big Data Mining and Applications, Fujian University of Technology, Fuzhou, China

3 Faculty of Electrical Engineering and Computer Science, VSB – Technical University of Ostrava, Ostrava, Czech Republic

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Chapter 4

Influence of Bit Depth on Objective Video Quality Assessment for High Resolutions

Juraj Bienik, Miroslav Uhrina and Peter Kortis

Additional information is available at the end of the chapter

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Abstract

This paper deals with the influence of bit depth on the objective quality assessment. All tests were conducted on eight video sequences, while each one has different spatial and temporal information; 8-bit and 10-bit bit depths were used; analysed videos were in full and ultra HD resolutions, and coding efficiency of H.264 and H.265 was compared. The metrics PSNR and SSIM for evaluation of objective video quality were used.

Keywords: bit depth, H.264/AVC, H.265/HEVC, objective assessment, PSNR, SSIM

1. Introduction

In recent years, the level of video multimedia services has increased rapidly. This evolution was allowed by increase of bandwidth of communication networks. Despite the fact that the capacity of certain network access technologies is up to hundreds or thousands of megabits per second (depending on the type of technology), the video compression is still hot and a current topic.

The rest of the paper is divided as follows. In the first part, the short characteristic of H.264 and H.265 compression standards is written. The second part describes briefly objective metrics used in our experiments. In the last part, the measurements and experimental results are described.

2. State of the art

Even if in papers [1–3] the coding efficiency comparison of well-known and most used compression standards as H.264/AVC, H.265/HEVC and VP9 using objective metrics has been

researched, in this paper, only sequences in HD and full HD resolutions were compared, objective quality assessment for ultra HD resolution was missing. In papers [4–8], the objective quality assessment of the newest compression standards as H.265/HEVC and VP9 has been examined, but the reference and still the most used compression standard H.264 was not taken into account. In papers [9–11], only the quality of multimedia services has been explored. In all mentioned papers [1–11], the influence of bit depth for objective quality assessment was not analysed. Therefore the aim of this paper is to determine coding efficiency of H.264 and H.265 compression standards for FHD and UHD resolutions depending on content of sequence and 8- and 10-bit bit depth using objective metrics.

3. H.264/AVC and H.265/HEVC compression standards

H.264/AVC is still one of the most used compression standards. It has been developed and designed for a wide range of multimedia services and video applications. The range of use is from video for cell phones through web applications to TV broadcasting (HDTV). H.264/AVC also defines profiles and levels, but only three profiles are currently defined: baseline, main and extended [12].

The High Efficiency Video Coding known as HEVC/H.265 is a recent video project of the ITU-T Video Coding Experts Group (VCEG) and the ISO/IEC Moving Picture Experts Group (MPEG) standardization organizations, and this collaboration is known as the Joint Collaborative Team on Video Coding (JCT-VC). H.265 has been developed in January 2013, and it is direct successor to H.264/AVC standards. The basic structure stays the same like as in H.264; it contains many incremental improvements which make him more effective [13].

4. Objective video quality assessment methods

The video quality assessment is commonly divided into the two groups—objective and subjective assessments.

The subjective evaluation is based on assessments by the observers—assessors score the video quality in appropriate scale. An advantage of this way is the result accuracy (determine exactly end recipient of video information); drawbacks of this method are that it is very time-consuming and for evaluation, many people are needed (in accordance with ITU-R BT.500-13, minimum of 15 observers for each test are needed).

Vice versa, the objective quality assessment is executed by computers that allow quick evaluation in all the time, and it is not limited by the assessment duration and times of repetition. From the mentioned reason, the objective assessment is mainly used. It consists of the use of computational methods which produce values that score the video quality. The big advantage of this type of assessment is the repeatability. Nowadays many objective metrics exist. Mostly used are peak signal-to-noise ratio (PSNR) and structural similarity index (SSIM).

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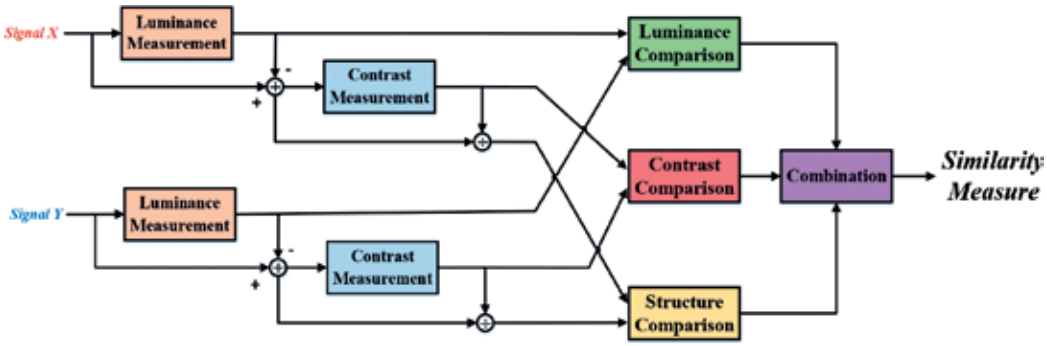

Figure 1. Block diagram of SSIM metric.

The PSNR is the oldest objective metric and considering its simplicity and computing speed still one of the most used. It is defined in [14]. The PSNR belongs to pixel-based metrics. The value of PSNR is derived from mean square error (MSE) and defined as:

$$\mathrm{PSNR} = 10 \cdot \log \frac{I^2}{\mathrm{MSE}} = 10 \cdot \log \frac{I^2}{\left(\frac{1}{TXY} \sum_t \sum_x \sum_y [x_0(x,y,t) - x_r(x,y,t)]^2\right)} [\mathrm{dB}],$$

where x_0 and x_r are two consecutive frames of sequence, $X.Y$ is the size of frame in pixels, T is the count of frames in the sequence and I is maximum value that a pixel can take. The value I is defined by bit depth as follows:

$$I = 2^b - 1,$$

where b is the bit depth.

The SSIM metric uses the structural distortion measurement instead of the error one. It measures three components—the luminance, the contrast and the structural similarity—and combines them into one final value which determines the quality of the test sequence (**Figure 1**).

SSIM metric reaches a very good correlation with subjective perception [15]. The results are given in interval [0-1] where 0 represents the worst and 1 the best quality.

5. Measurement procedure

In this experiment, eight video test sequences are used. The sequences are part of database [16]. The next paragraphs contain short description of used sequences.

- **Bund nightscape**—city night shot. The scene is time lapsed; the dynamic segments of scene are moving cars and walkers on the curb; static segments are represented by urban buildings. The camera captures scene from static position (**Figure 2**).

- **Campfire party**—night scene close the fire. In the front of the image, there is flaming bonfire (the fast change of temporal and luminance information). In the background of the image, there is a group of slightly static people. At the end of the sequence, the camera zooms on the group of people (**Figure 3**).
- **Construction field**—shot on the construction site, where the static background is represented by buildings under construction, dynamic objects are represented by construction vehicles (excavator) and walking workers. The slow-motion scene is captured statically (**Figure 4**).
- **Fountains**—the daily shot on the city fountain. The foreground consists of squirting water (a lot of edges in the picture); the background is static formed by trees and the buildings. The capturing is static, scene with low dynamic of motion (**Figure 5**).
- **Marathon**—marathon competition. The runners are multiple moving objects with moderate dynamic; the background is a static road. The camera capturing is static from high point of view (**Figure 6**).
- **Runners**—the running challenge, but in contrast to "marathon scene", there are fewer runners. The camera is static, located in the front of the runners slightly angled to the side (higher spatial information). Scene is relatively dynamic (**Figure 7**).
- **Tall buildings**—the shot on the modern city. The static objects are skyscrapers, river and the urban infrastructure; the slow-motion objects are represented by city traffic. The camera is moving slowly form the left to the right side. The scene is characteristic with the change of spatial and temporal information (**Figure 8**).
- **Wood**—the forest scenery. The shot on the trees in the forest (captured objects are static). The motion of the camera is from the left to the right side, and the motion is accelerating in the sequence. Relatively high value of the spatial and temporal information (**Figure 9**).

Figure 2. Bund nightscape.

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Figure 3. Campfire party.

Figure 4. Construction field.

Figure 5. Fountains.

Generally, the compression difficulty is directly related to the spatial and temporal information of a sequence. Regarding [17], the spatial information (SI) and temporal information (TI) using the Mitsu tool [18] was calculated. According to results the spatial-temporal information plane was drawn (**Figure 10**).

Figure 6. Marathon.

Figure 7. Runners.

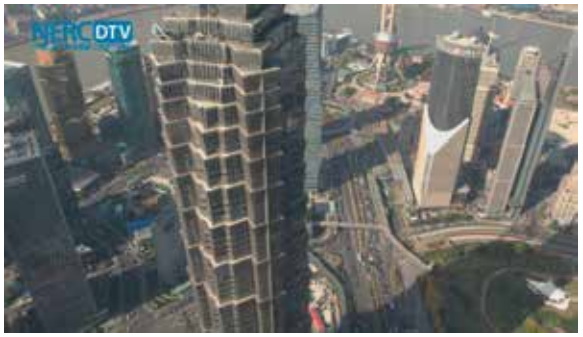

Figure 8. Tall buildings.

According to [17], eight test sequences were used in a test.

All sequences were uncompressed in *.yuv format, in UHD resolution (3840 × 2160 px). The aspect ratio of all sequence was 16:9, framerate was 30fps (frames per second) and used chroma subsampling was 4:4:4. The length of these sequences was 300 frames, that is, 10 s.

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Figure 9. Wood.

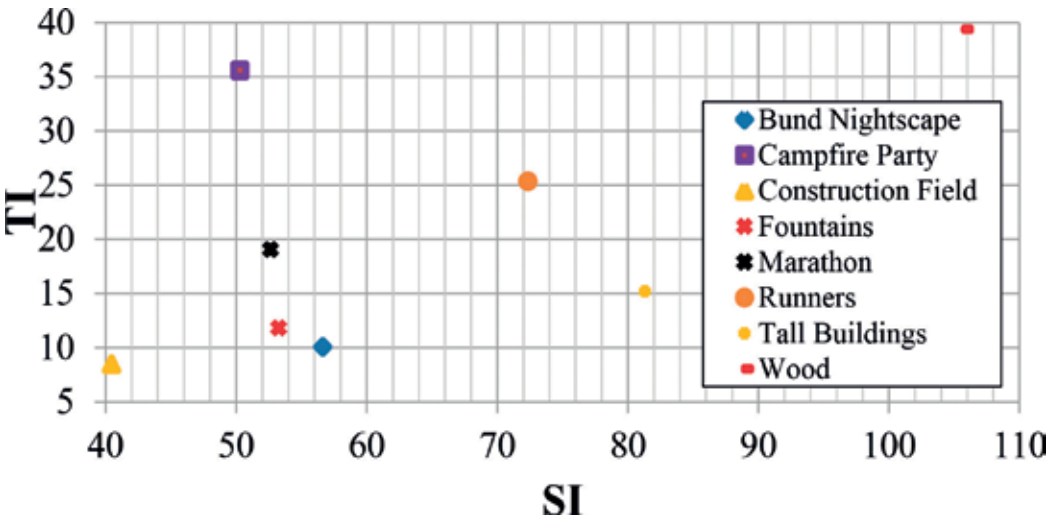

Figure 10. Spatial-temporal information of test sequences.

The measurement procedure consists of four steps:

1. First, all sequences were downloaded from [16] in the uncompressed format (*.yuv) and used as the reference ones.
2. Afterwards, they were encoded to both H.264/AVC and H.265/HEVC compression standards using the FFmpeg and x264/x265 tool [19–21]. The target bitrates were 1, 3, 5, 10 and 15 Mbps; bit depth 8 and 10 bits for FHD and UHD, chroma subsampling 4:2:0 were used. GOP size was set to M = 3 and N = 15.
3. Then, the sequences were decoded using the same tool back to the format *.yuv.
4. Finally, the quality between these sequences and the reference (uncompressed) one was compared and evaluated. This was done using the MSU Measuring Tool Pro version 3.0 [22]. PSNR and SSIM objective metrics for the measurements were used.

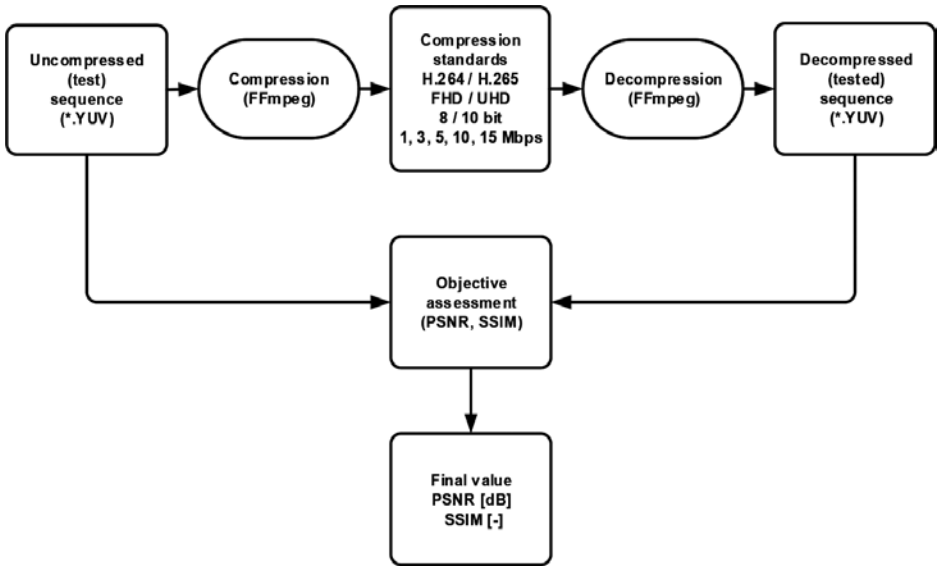

Figure 11. The whole procedure of measurement and evaluation the impact of both compression standards on the video quality.

The whole procedure of measurement and evaluation is represented in **Figure 11**.

6. Experimental results

All experiments using eight abovementioned video test sequences with different codecs, video resolutions, bitrates and bit depths were performed. The list of all parameters is in **Table 1**.

For every combination of test parameters, the value of PSNR and SSIM was computed. The obtained dataset consists of 320 values of PSNR and SSIM. Because the obtained number of results is massive, only the presented parameters are published:

- The **PSNR** difference between H.264 and 265 codec: $PSNR_{H.265} - PSNR_{H.264}$
- The **relative** SSIM difference between H.264 and 265 codec: $\frac{\mathrm{SSIM}_{H.265} - \mathrm{SSIM}_{H.264}}{\mathrm{SSIM}_{H.264}}$
- The **PSNR** difference between 10- and 8-bit bit depth: $PSNR_{10bit} - PSNR_{8bit}$
- The **relative** SSIM difference between 10- and 8-bit bit depth: $\frac{\mathrm{SSIM}_{10bit} - \mathrm{SSIM}_{8bit}}{\mathrm{SSIM}_{8bit}}$

In the first part, the **full HD** video sequences were analysed.

Tables 2–5 and **Figure 13** show the difference between codecs. The last column of tables contains average values computed for specific bitrate. **Figure 12** shows coding efficiency comparison of H.264 and H.265 in full HD with 8-bit bit depth (left) and with 10-bit bit depth (right).

Parameter	Values
Video test sequence	Bund nightscape, Campfire party, Construction field, Fountains, Marathon, Runners, Tall buildings, Wood
Codec	H.264, H.265
Video resolution	Full HD (FDH), ultra HD (UHD)
Bitrate (Mbps)	1, 3, 5, 10, 15
Bit depth (bit)	8, 10

Table 1. The list of parameter settings of performed experiments.

Bitrate (Mbps)	Bund nightscape (dB)	Campfire party (dB)	Construction field (dB)	Fountains (dB)	Marathon (dB)	Runners (dB)	Tall buildings (dB)	Wood (dB)	AVG (dB)
1	1.54	2.67	1.89	0.85	1.55	1.46	2.21	1.91	1.76
3	1.36	1.58	1.64	0.41	0.84	0.99	1.84	1.29	1.24
5	1.22	1.20	1.30	0.28	0.64	0.80	1.59	1.04	1.01
10	1.07	0.92	0.99	0.13	0.40	0.45	1.29	0.87	0.77
15	0.86	0.78	0.97	0.06	0.29	0.31	1.20	0.77	0.66

Table 2. PSNR difference between H.264 and 265 codecs for FHD and 8-bit bit depth.

Bitrate (Mbps)	Bund nightscape (%)	Campfire party (%)	Construction field (%)	Fountains (%)	Marathon (%)	Runners (%)	Tall buildings (%)	Wood (%)	AVG (%)
1	1.45	5.47	3.19	3.19	5.87	13.78	9.24	8.13	1.45
3	0.44	2.58	0.93	1.18	1.22	2.76	2.52	1.78	0.44
5	0.25	1.44	0.50	0.85	0.55	1.16	1.12	0.71	0.25
10	0.27	0.78	0.30	0.47	0.18	0.24	0.35	0.15	0.27
15	0.17	0.57	0.29	0.31	0.14	0.07	0.25	0.07	0.17

Table 3. Relative SSIM difference between H.264 and 265 codecs for FHD and 8-bit bit depth.

The relative SSIM difference between H.264 and H.265 compression standard is more significant for low bitrates in full HD resolution (**Figure 13**). For 8-bit bit depth, the value is very close for bitrates 10 Mbps and higher. If the 10-bit bit depth is used, the value of relative SSIM is different for scenes Fountains and Campfire Party for bitrate 5 Mbps and higher. The trend of relative SSIM is similar for 8- and 10-bit bit depth, but the values for 8-bit bit depth are slightly higher for lower bitrates.

Bitrate (Mbps)	Bund nightscape (dB)	Campfire party (dB)	Construction field (dB)	Fountains (dB)	Marathon (dB)	Runners (dB)	Tall buildings (dB)	Wood (dB)	AVG (dB)
1	1.82	2.32	1.65	0.71	1.87	1.48	2.09	1.94	1.73
3	1.74	2.00	1.39	0.79	1.14	0.99	2.10	1.77	1.49
5	1.60	1.72	1.14	0.82	0.93	0.83	1.85	1.64	1.32
10	1.32	1.43	0.78	0.61	0.58	0.60	1.49	1.40	1.03
15	0.99	1.19	0.73	0.64	0.44	0.47	1.36	1.33	0.89

Table 4. PSNR difference between H.264 and 265 codecs for FHD and 10-bit bit depth.

Bitrate (Mbps)	Bund nightscape (%)	Campfire party (%)	Construction field (%)	Fountains (%)	Marathon (%)	Runners (%)	Tall buildings (%)	Wood (%)	AVG (%)
1	1.47	5.93	2.64	2.45	7.81	12.19	8.35	8.03	1.47
3	0.48	3.69	0.71	1.99	1.68	2.32	2.64	2.28	0.48
5	0.28	2.33	0.37	1.81	0.85	1.03	1.22	1.12	0.28
10	0.14	1.22	0.14	1.46	0.26	0.30	0.42	0.36	0.14
15	0.10	0.78	0.13	1.30	0.16	0.14	0.24	0.18	0.10

Table 5. Relative SSIM difference between H.264 and 265 codecs for FHD and 10-bit bit depth.

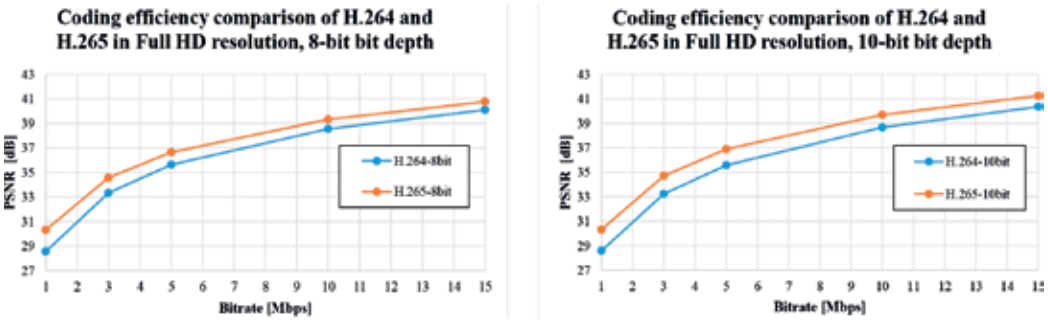

Figure 12. Coding performance comparison of H.264 and H.265 for full HD resolution, 8- and 10-bit bit depth (PSNR metric).

Tables 6–9 show the metrics for different bitrates and scenes. **Tables 6** and **8** show results for codec H.264 and **Tables 7** and **9** for H.265, respectively. The positive values in the table are marked with red colour. The positive value indicates that 10-bit bit depth outperforms 8-bit bit depth in FHD video sequence.

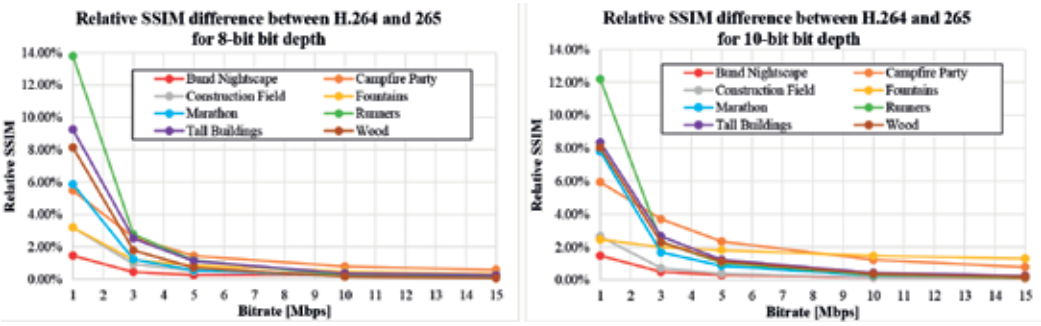

Figure 13. Relative SSIM difference between H.264 and H.265 compression standards for 8-bit (left) and 10-bit bit depth (right) in FHD.

Bitrate (Mbps)	Bund nightscape (dB)	Campfire party (dB)	Construction field (dB)	Fountains (dB)	Marathon (dB)	Runners (dB)	Tall buildings (dB)	Wood (dB)	AVG (dB)
1	−0.36	0.22	0.21	0.39	−0.29	0.03	0.05	−0.07	0.02
3	−0.26	−0.43	0.38	−0.01	−0.08	0.08	−0.08	−0.40	−0.10
5	−0.04	−0.34	0.55	−0.12	−0.03	0.03	−0.02	−0.46	−0.05
10	0.62	−0.24	0.86	−0.05	0.00	−0.02	0.09	−0.30	0.12
15	1.17	−0.07	1.02	−0.16	0.07	0.03	0.21	−0.22	0.26

Note: The 10-bit bit depth outperforms 8-bit only 17 times.

Table 6. PSNR difference between 10- and 8-bit bit depths for H.264—FHD.

Bitrate (Mbps)	Bund nightscape (dB)	Campfire party (dB)	Construction field (dB)	Fountains (dB)	Marathon (dB)	Runners (dB)	Tall buildings (dB)	Wood (dB)	AVG (dB)
1	−0.08	−0.14	−0.03	0.25	0.03	0.05	−0.07	−0.03	0.00
3	0.11	−0.02	0.13	0.36	0.22	0.07	0.18	0.07	0.14
5	0.34	0.18	0.39	0.42	0.26	0.06	0.24	0.14	0.25
10	0.87	0.27	0.64	0.43	0.18	0.13	0.30	0.23	0.38
15	1.29	0.34	0.78	0.42	0.21	0.19	0.37	0.34	0.49

Note: The 10-bit bit depth outperforms 8-bit 34 times.

Table 7. PSNR difference between 10- and 8-bit bit depths for H.265—FHD.

From **Table 6**, we can state that the best result of PSNR difference of FHD indicates sequences Construction field and Runners (scenes with slow dynamic); the worst result is in the scene Wood, which contains the most spatial and temporal information. Average enhancement with 10-bit bit depth is only 0.05 dB. Commonly, quality enhancement coefficient strongly depends on content of test sequence.

Bitrate (Mbps)	Bund nightscape (%)	Campfire party (%)	Construction field (%)	Fountains (%)	Marathon (%)	Runners (%)	Tall buildings (%)	Wood (%)	AVG (%)
1	−0.12	−0.4	0.51	1.67	−1.32	1.20	0.26	−0.50	0.16
3	0.13	−0.93	0.38	0.02	0.04	0.39	0.00	−0.68	−0.08
5	0.22	−0.60	0.37	−0.22	0.16	0.04	0.03	−0.46	−0.06
10	0.43	−0.20	0.42	−0.44	0.18	−0.12	0.00	−0.22	0.01
15	0.39	0.03	0.42	−0.57	0.23	−0.11	0.05	−0.13	0.04

Note: The 10-bit bit depth outperforms 8-bit 23 times.

Table 8. Relative SSIM difference between 10- and 8-bit bit depths for H.264—FHD.

Bitrate (Mbps)	Bund nightscape (%)	Campfire party (%)	Construction field (%)	Fountains (%)	Marathon (%)	Runners (%)	Tall buildings (%)	Wood (%)	AVG (%)
1	−0.10	0.02	−0.02	0.94	0.49	−0.22	−0.56	−0.60	0.00
3	0.18	0.14	0.16	0.82	0.50	−0.05	0.12	−0.19	0.21
5	0.25	0.27	0.24	0.73	0.46	−0.08	0.14	−0.05	0.24
10	0.30	0.24	0.26	0.54	0.26	−0.05	0.07	−0.01	0.20
15	0.33	0.23	0.27	0.41	0.25	−0.05	0.04	−0.02	0.18

Note: The 10-bit bit depth outperforms 8-bit 27 times.

Table 9. Relative SSIM difference between 10- and 8-bit bit depth for H.265—FHD.

Table 7 shows influence of 10-bit bit depth for H.265 compression standard. If we compare **Table 7** with **Table 6**, we can state that efficiency of H.265 with 10-bit bit depth is rapidly higher than (even the 34 positive cases). In the rest of cases, negative difference is very small and not significant. It leads to the conclusion that encoded videos are suitable for practical implementation.

Table 8 indicates slightly better results in comparison with **Table 6**; probably this result will better correlate with evaluations from subjective video quality assessment. This table indicates that the relative quality enhancement with 10-bit depth for H.264 and FHD resolution is in 23 cases. It leads to conclusion that efficiency of mentioned compression standard with 10-bit bit depth is low and not appropriate for practical applications.

Table 9 shows relative SSIM differences between 8-bit and 10-bit bit depths for H.265 in full HD resolution. The reference chosen was 8-bit bit depth. In all sequences 10-bit bit depth outperformed 8-bit; exemptions are only sequences Runners and Wood, which indicate high level of spatial information, but nevertheless the negative differences are so small—close to zero.

Figure 14 complexly summarizes results from **Tables 6–9**. Values of PSNR difference are on the left vertical axis; the right axis shows results with relative differences from the SSIM metric. Horizontal axis represents used bitrate.

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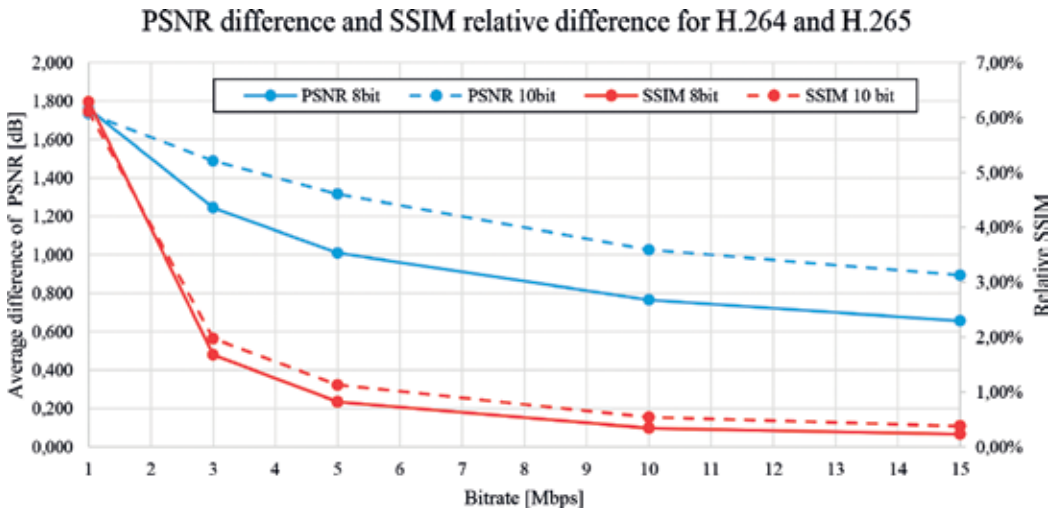

Figure 14. The PSNR difference and SSIM relative difference for FHD resolution, H.264 and H.265 compression standards and for different bitrates.

From **Tables 6–9** and **Figure 11**, we can state that 10-bit bit depth for H.264 in full HD resolution is not significant (only nearly half cases that quality increased); for H.265 the increase of quality is higher and should be a good choice for practical application.

In the next part, the **ultra HD** video sequences were analysed.

Tables 10–14 show the difference between codecs. The last column of tables contains average values computed for specific bitrate.

The relative SSIM difference between H.264 and H.265 compression standards is more significant for low bitrates (**Figure 15**). For 8-bit bit depth, the value is very close for bitrates 10 Mbps and higher. If we compare results from **Figures 13** and **15**, we can state that better results in percentage of SSIM should be achieved with UHD resolution.

Bitrate (Mbps)	Bund nightscape (dB)	Campfire Party (dB)	Construction Field (dB)	Fountains (dB)	Marathon (dB)	Runners (dB)	Tall Buildings (dB)	Wood (dB)	AVG (dB)
1	2.43	2.08	2.85	0.69	2.33	2.20	3.32	4.71	2.58
3	1.71	3.05	1.68	0.64	2.31	2.22	2.86	3.08	2.19
5	1.38	2.57	1.16	0.67	1.66	1.68	2.42	2.45	1.75
10	0.83	1.23	0.52	0.44	0.78	0.87	1.86	1.64	1.02
15	0.51	0.86	0.44	0.41	0.56	0.61	1.43	1.37	0.77

Table 10. PSNR difference between H.264 and 265 codecs for UHD and 8-bit bit depth.

Bitrate (Mbps)	Bund nightscape (%)	Campfire party (%)	Construction field (%)	Fountains (%)	Marathon (%)	Runners (%)	Tall buildings (%)	Wood (%)	AVG (%)
1	3.24	3.41	5.33	1.42	3.92	7.56	16.96	18.58	7.55
3	1.08	4.37	2.30	0.53	5.17	11.07	8.45	8.82	5.22
5	0.67	3.64	1.39	0.88	3.04	6.45	5.01	4.50	3.20
10	0.30	1.75	0.56	0.59	1.23	2.05	2.27	1.56	1.29
15	0.17	1.29	0.55	0.64	0.90	1.06	1.23	0.92	0.85

Table 11. Relative SSIM difference between H.264 and 265 codecs for UHD and 8-bit bit depth.

Bitrate (Mbps)	Bund nightscape (dB)	Campfire party (dB)	Construction field (dB)	Fountains (dB)	Marathon (dB)	Runners (dB)	Tall buildings (dB)	Wood (dB)	AVG (dB)
1	2.86	12.78	2.49	0.72	4.32	3.40	3.19	8.95	4.84
3	1.81	3.26	1.38	0.88	2.40	2.21	2.28	2.65	2.11
5	1.48	2.71	0.85	0.79	1.70	1.76	2.31	1.95	1.69
10	0.89	2.02	1.08	0.77	1.17	1.35	1.90	1.54	1.34
15	0.34	1.43	0.23	0.85	0.88	1.08	1.49	1.32	0.95

Table 12. PSNR difference between H.264 and 265 codecs for UHD and 10-bit bit depth.

Bitrate (Mbps)	Bund nightscape (%)	Campfire party (%)	Construction field (%)	Fountains (%)	Marathon (%)	Runners (%)	Tall Buildings (%)	Wood (%)	AVG (%)
1	3.91	14.17	4.74	2.01	6.71	16.34	17.11	22.06	10.88
3	1.14	5.67	1.98	1.94	5.66	10.51	6.37	7.22	5.06
5	0.70	4.02	1.03	1.77	3.37	6.73	4.63	3.45	3.21
10	0.31	3.20	1.13	1.65	1.97	3.35	2.23	1.58	1.93
15	0.11	2.28	0.24	1.70	1.46	2.02	1.26	0.98	1.26

Table 13. Relative SSIM difference between H.264 and 265 codec for UHD and 10-bit bit depth.

Tables 14–17 show the metrics for different bitrates and scenes. **Tables 14** and **16** show results for codec H.264 and **Tables 15** and **17** for H.265, respectively. The positive values in the table are marked with red colour. The positive value indicates that 10-bit bit depth outperforms 8-bit in UHD video sequence.

Bitrate (Mbps)	Bund nightscape (dB)	Campfire party (dB)	Construction field (dB)	Fountains (dB)	Marathon (dB)	Runners (dB)	Tall buildings (dB)	Wood (dB)	AVG (dB)
1	−0.15	−8.63	0.32	0.20	−1.24	−0.39	−0.18	−4.00	−1.76
3	0.14	−0.33	0.28	−0.02	0.07	0.08	0.39	0.11	0.09
5	0.22	−0.26	0.31	0.12	0.14	0.03	0.03	0.31	0.11
10	0.31	−0.61	−0.51	0.03	−0.05	−0.24	0.03	0.00	−0.13
15	0.36	−0.37	0.27	−0.04	−0.02	−0.22	0.06	0.01	0.01

Note: The 10-bit bit depth outperforms 8-bit only 22 times.

Table 14. PSNR difference between 10- and 8-bit bit depths for H.264—UHD.

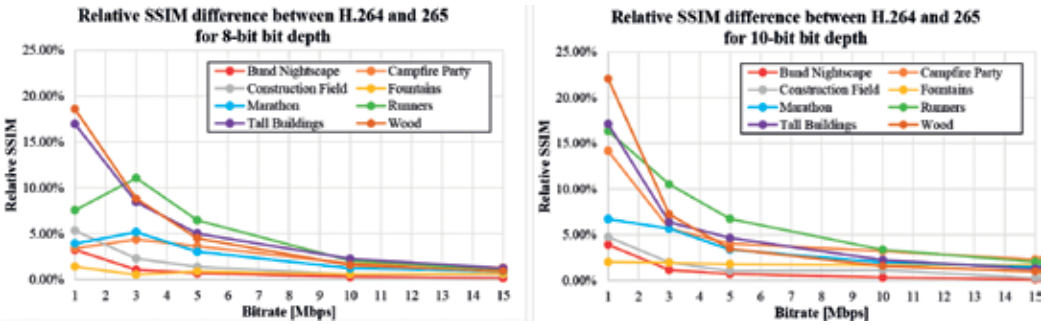

Figure 15. Relative SSIM difference between H.264 and H.265 compression standards for 8-bit and 10-bit bit depths and UHD.

Bitrate (Mbps)	Bund nightscape (dB)	Campfire party (dB)	Construction field (dB)	Fountains (dB)	Marathon (dB)	Runners (dB)	Tall buildings (dB)	Wood (dB)	AVG (dB)
1	0.27	2.08	−0.04	0.22	0.75	0.81	−0.32	0.24	0.50
3	0.24	−0.13	−0.01	0.21	0.15	0.07	−0.19	−0.32	0.00
5	0.32	−0.12	0.01	0.24	0.18	0.12	−0.08	−0.19	0.06
10	0.37	0.18	0.06	0.35	0.33	0.23	0.07	−0.10	0.19
15	0.19	0.20	0.06	0.40	0.30	0.25	0.11	−0.04	0.18

Note: The 10-bit bit depth outperforms 8-bit 29 times.

Table 15. PSNR difference between 10- and 8-bit bit depths for H.265—UHD.

From **Tables 14–17** and **Figure 16**, we can state that 10-bit bit depth with H.264 compression standard in UHD resolution is not appropriate; vice versa H.265 with 10-bit bit depth indicates quality increment in UHD resolution.

Bitrate (Mbps)	Bund nightscape (%)	Campfire party (%)	Construction field (%)	Fountains (%)	Marathon (%)	Runners (%)	Tall buildings (%)	Wood (%)	AVG (%)
1	−0.08	−7.08	0.73	0.30	−0.07	−2.53	−1.43	−1.19	−1.42
3	0.29	−1.09	0.50	−0.03	0.54	0.74	1.49	0.43	0.36
5	0.31	−0.22	0.49	0.25	0.58	0.37	0.23	0.69	0.34
10	0.32	−0.83	−0.44	0.02	0.08	−0.57	0.16	0.05	−0.15
15	0.34	−0.50	0.43	−0.08	0.12	−0.43	0.12	0.07	0.01

Note: The 10-bit bit depth outperforms 8-bit 25 times.

Table 16. Relative SSIM difference between 10- and 8-bit bit depths for H.264—UHD.

Bitrate (Mbps)	Bund nightscape (%)	Campfire party (%)	Construction field (%)	Fountains (%)	Marathon (%)	Runners (%)	Tall buildings (%)	Wood (%)	AVG (%)
1	0.56	2.59	0.17	0.88	2.60	5.43	−1.31	1.70	1.58
3	0.35	0.15	0.18	1.38	1.01	0.23	−0.46	−1.05	0.22
5	0.34	0.14	0.13	1.13	0.90	0.63	−0.14	−0.32	0.35
10	0.33	0.58	0.13	1.08	0.82	0.69	0.12	0.06	0.48
15	0.28	0.47	0.11	0.97	0.68	0.52	0.15	0.13	0.41

Note: The 10-bit bit depth outperforms 8-bit 35 times.

Table 17. Relative SSIM difference between 10- and 8-bit bit depths for H.265—UHD.

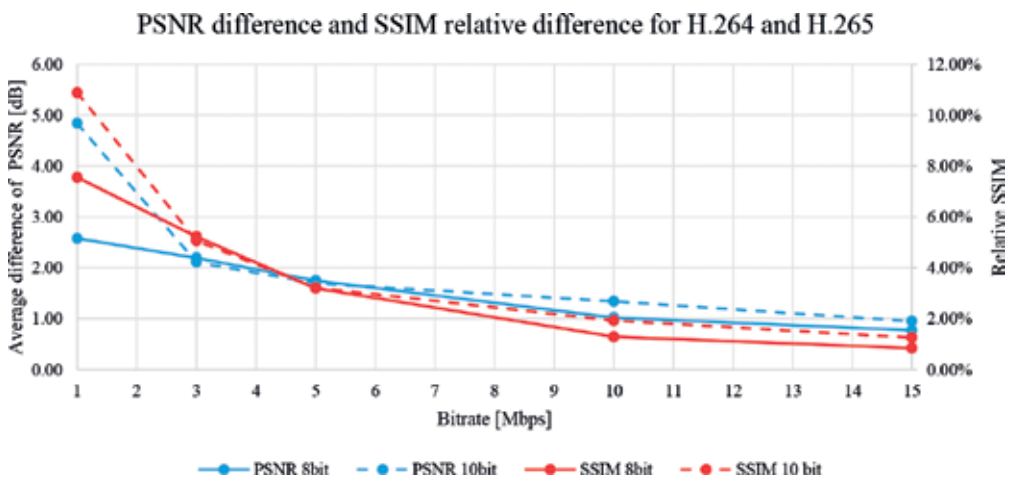

Figure 16. The PSNR difference and SSIM relative difference for UHD resolution, H.264 and H.265 compression standards and for different bitrates.

We can also state that H.265 with 10-bit bit depth is more appropriate with ultra HD resolution than full HD (more significant quality increment). The biggest efficiency H.265 indicates in low bitrates (from 1 to 3 Mbps).

According to the experimental results and graphs, several conclusions can be pronounced:

1. The quality of both compression standards rises logarithmically with increasing bitrate—in low bitrates the quality grows faster than in high bitrates (**Figure 12**).
2. By comparing both codecs, it can be generally said that the bigger difference in quality is in lower bitrates—with increasing bitrate the quality of H.264/AVC codec approaches the H.265/HEVC codec (**Figure 16**).
3. The coding efficiency of H.265/HEVC standard is more visible in UHD resolution.
4. The effectiveness of compression depends on the types of test sequences.

7. Conclusion

In this paper the impact of H.265/HEVC and H.264/AVC compression standards and bit depth on the video quality for high resolutions using objective metrics and determining their efficiency was presented. The assessment was done for eight types of sequences with full HD and ultra HD resolutions depending on the content. The experimental results showed that H.265/HEVC codec yields better compression efficiency than H.264/AVC and 10-bit bit depth significantly increment video quality in combination with H.265/HEVC. The bigger difference in quality is in lower bitrates—with increasing bitrate, the quality of H.264/AVC codec approaches the H.265/HEVC codec. The coding efficiency of H.265/HEVC standard is more visible in UHD resolution.

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Author details

Juraj Bienik*, Miroslav Uhrina and Peter Kortis

*Address all correspondence to: juraj.bienik@fel.uniza.sk

Department of Multimedia and Information-Communication Technologies, Faculty of Electrical Engineering, University of Zilina, Zilina, Slovakia

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Chapter 5

Influence of Chroma Subsampling on Objective Video Quality Assessment for High Resolutions

Miroslav Uhrina, Juraj Bienik and Peter Kortis

Additional information is available at the end of the chapter

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Abstract

This paper deals with the influence of chroma subsampling on video quality measured by objective metrics for H.264/AVC and H.265/HEVC compression standards. The evaluation is done for eight types of sequences with full HD and ultra HD resolutions depending on content. The experimental results showed that there is no impact of chroma subsampling on the video. According to the results, it can also be said that H.265/HEVC codec yields better compression efficiency than H.264/AVC and the different is more visible in UHD resolution. The bigger difference in quality is in lower bitrates, with increasing bitrate the quality of H.264/AVC codec approaches the H.265/HEVC codec.

Keywords: chroma subsampling, H.264/AVC, H.265/HEVC, objective assessment, PSNR, SSIM

1. Introduction

Recently, the interest of multimedia services has rapidly increased, which has reflected also in the use of higher resolutions. The future trend will be moved from Full HD to Ultra HD resolution. This fact results in the need for higher bandwidth as well as the need to develop new compression standards. That also leads to the demand of video quality assessment. Last year's many new compression standards have become available, e.g. H.265/HEVC or VP9, and many others are being still developed as DAALA or VP10.

2. State of the art

Even if in papers [1–3] the coding efficiency comparison of well-known and most used compression standards such as H.264/AVC, H.265/HEVC and VP9 using objective metrics has

been researched, but in these papers only sequences in HD and Full HD resolutions were compared, objective quality assessment for Ultra HD resolution was missing. In papers [4–8], the objective quality assessment of the newest compression standards such as H.265/HEVC and VP9 has been examined, but the reference and still the most used compression standard H.264 were not taken into account. In papers [9–11], only the quality of multimedia services has been explored. In all mentioned papers [1–11], the influence of chroma subsampling on the video quality has not been analyzed. Therefore, the aim of this paper is to parse how the chroma subsampling affects the video quality measured by selected objective metrics.

3. Chroma subsampling

Chroma subsampling is the practice of encoding images by implementing less resolution for chroma information than for luma information. This is due to our human visual system which is less sensitive to color than to luminance. So, the video system can be optimized by devoting more bandwidth to the luma component (usually denoted as Y or Y′ after gamma correction) than to the color difference components, Cb and Cr. The subsampling scheme is commonly expressed as a three part ratio J/a/b (e.g. 4:2:2). The parts are (in their respective order) (**Figure 1**):

- J: horizontal sampling reference (width of the conceptual region), usually 4.
- a: number of chrominance samples (Cr, Cb) in the first row of J pixels.
- b: number of changes of chrominance samples (Cr, Cb) between the first and second rows of J pixels.

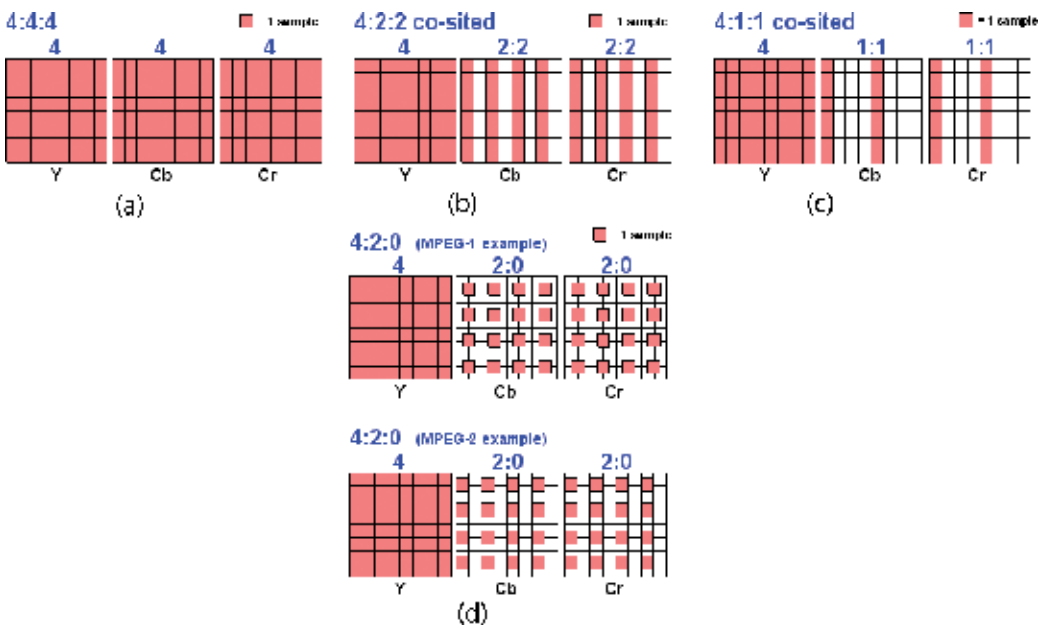

Figure 1. Chroma subsampling modes (a–d).

The most used subsampling schemes are 4:4:4, 4:2:2, 4:2:0 and 4:1:1.

a. 4:4:4: The Cb and Cr colors are sampled at the same rate as the luma (Y); thus, there is no chroma subsampling.

b. 4:2:2: Both chroma components (Cb and Cr) are sampled at half the horizontal resolution of the luma (Y), so the horizontal chroma resolution is halved. This reduces the bandwidth of an uncompressed video signal by one-third with little to no visual difference.

c. 4:2:0: Both chroma components (Cb and Cr) are sampled at half the vertical resolution of Y, so the bandwidth is halved compared to no chroma subsampling.

d. 4:1:1: Both chroma components (Cb and Cr) are sampled at one quarter the horizontal resolution, so the bandwidth is the same as by 4:2:0 subsampling scheme [12, 13].

4. H.264/AVC and H.265/HEVC compression standards

Although H.264/AVC codec was developed in 2003, it is still one of the most used compression standards. It has been designed for a wide range of applications, ranging from video for mobile phones through web applications to TV broadcasting (HDTV). H.264/AVC also defines profiles and levels. There are only three profiles currently defined: baseline, main and extended [14].

The High Efficiency Video Coding known as HEVC/H.265 was developed in January 2013 by a partnership known as the Joint Collaborative Team on Video Coding (JCT-VC), which arose by the cooperation of the ITU-T Video Coding Experts Group (VCEG) and the ISO/IEC Moving Picture Experts Group (MPEG) standardization organizations. It is the newest coding standard from the MPEG family codecs. It contains many improvements, which makes him more effective than the previous standards [15].

5. Objective video quality assessment methods

In general, the video quality assessment can be divided into objective and subjective parts. The subjective evaluation consists of the use of people: assessors who rate the video quality. Even if it is the most reliable way to determine the video quality, it has a big disadvantage: it is time-consuming because minimum 15 observers for each test are needed (according to ITU-R BT.500-13 recommendation). Because of this drawback, in many cases, the objective assessment is used. It consists of the use of computational methods, which score the video quality. The biggest advantage of this type of assessment is that it has opportunity to easily repeat the tests. Today, many objective metrics exist. Mostly used are peak signal-to-noise ratio (PSNR) and structural similarity index (SSIM).

Although the PSNR [16] is the oldest and easiest objective metric, it is still used.

The SSIM metric measures three components—the luminance, the contrast and the structural similarity—and combines them into one final value which determines the quality. It reaches a very good correlation with subjective perception [17]. The results are given in interval [0,1] where 0 represents the worst and 1 the best quality.

6. Measurement procedure

In this experiment, eight video test sequences, according to different temporal and spatial information, were used. All sequences are the part of the database [18]. In the next part, a brief description of used sequences is written:

- **Bund nightscape**—city night shot. The scene is time lapsed; the dynamic segments of scene are moving cars and walkers on the curb; static segments are represented by urban buildings. The camera captures scene from static position (**Figure 2a**).
- **Campfire party**—night scene closes to the fire. In the front of the image is flaming bonfire (the fast change of temporal and luminance information). In the background of the image is a group of slightly static people. At the end of the sequence, the camera zooms on the group of people (**Figure 2b**).
- **Construction field**—shot on the construction site, where the static background is represented by buildings under construction and dynamic objects are represented by construction vehicles (excavator) and walking workers. The slow-motion scene captured statically (**Figure 2c**).
- **Fountains**—the daily shot on the city fountain. The foreground consists of squirting water (a lot of edges in the picture); the background is static formed by trees and the buildings. The capturing is static, scene with low dynamic of motion (**Figure 2d**).
- **Marathon**—marathon competition. The runners are multiple moving objects with moderate dynamics; the background is a static road. The camera capturing is static from high point of view (**Figure 2e**).
- **Runners**—the running challenge; but in contrast to "marathon scene," there are fewer runners. The camera is static, located in the front of the runners slightly angled to the side (higher spatial information). Scene is relatively dynamic (**Figure 2f**).
- **Tall buildings**—the shot on the modern city. The static objects are skyscrapers, river and the urban infrastructure; the slow-motion objects are represented by city traffic. The camera is moving slowly from the left to the right side. The scene is characteristic with the change of spatial and temporal information (**Figure 2g**).
- **Wood**—the forest scenery. The shot on the trees in the forest (captured objects are static), the motion of the camera is from the left to the right side and the motion is accelerating in the sequence. Relatively high value of the spatial and temporal information (**Figure 2h**).

Generally, the compression difficulty is directly related to the spatial and temporal information of a sequence. Regarding to [19], the spatial (SI) and temporal information (TI) using the Mitsu tool [20] was calculated. According to the results, the spatial-temporal information plane was drawn (**Figure 3**).

The basic parameters of these sequences are shown in **Table 1**.

The measurement process consists of four steps:

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Figure 2. The test sequences (a–h).

1. The reference sequences were downloaded from Ref. [18] in the uncompressed format (*.yuv).
2. After that, all of them were encoded to H.264/AVC and H.265/HEVC compression standards using the FFmpeg tool [21]. The target bitrates were chosen to 1, 3, 5, 10, and 15 Mbps. The GoP size was set to the half of the frame rate, i.e. M = 3 and N = 15.
3. Subsequently, the sequences were back decoded to the format *.yuv using the same FFmpeg tool.

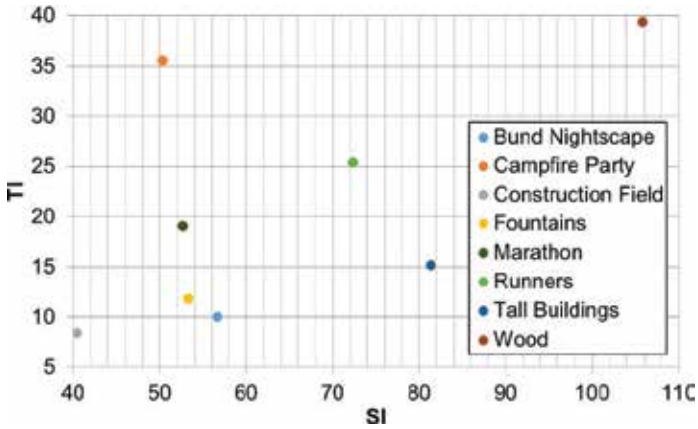

Figure 3. Spatial-temporal diagram of test sequences.

Resolution	Chroma subsampling	Bit depth	Aspect ratio	Frame rate (fps)	Length (frames)	Length (seconds)
3840×2160 (UHD)	4:4:4	10 bits per channel	16:9	30	300	10

Table 1. Basic parameters of the test sequences.

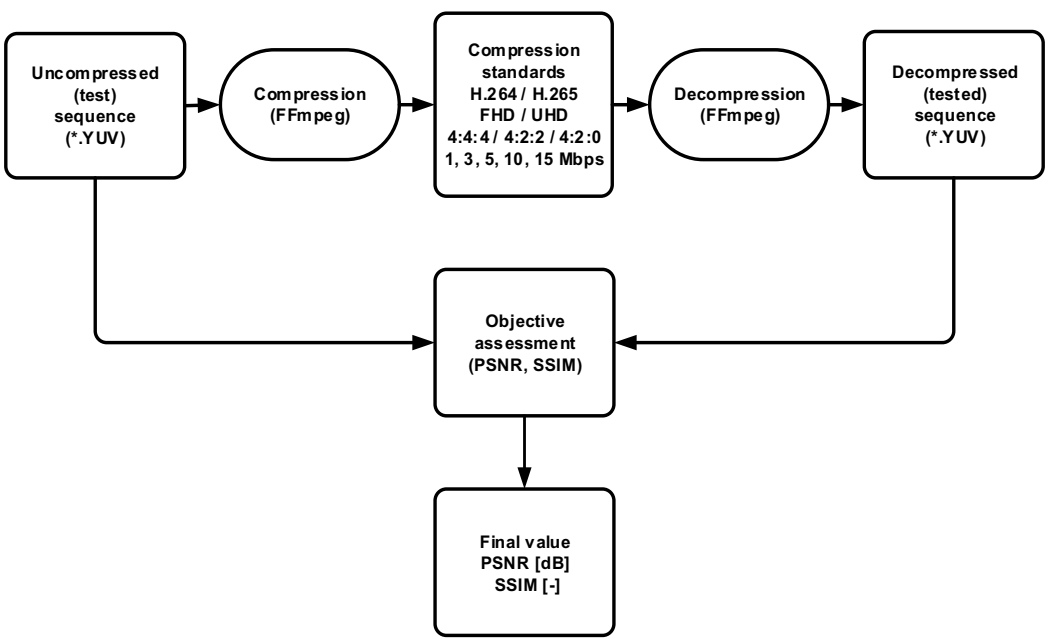

Figure 4. The whole procedure of the experiment.

4. Finally, the quality between these sequences and the reference (uncompressed) ones was compared and evaluated. This was done using the MSU Measuring Tool Pro version 3.0 [22]. For the measurement, the PSNR and SSIM objective metrics were used.

The whole procedure of measurement and evaluation is represented in **Figure 4**.

7. Experimental results

Figure 5 shows the ratio of the video quality (measured by PSNR and SSIM metrics) and bitrate of both compression standards for all test sequences for FHD resolution and UHD resolution. In **Figure 5**, eight graphs are inset: depending on the codec, resolution and used objective metric.

Figure 6 shows the impact of the chroma subsampling on the video quality measured by PSNR and SSIM metrics of both compression standards for all test sequences for FHD resolution and UHD resolution. In **Figure 6**, eight graphs are inset: depending on the codec, resolution and used objective metric.

Figure 7 demonstrates the difference of the coding efficiency between H.264 and H.265 codecs as well as the difference between FHD and UHD resolutions. This representation is done for five test sequences, which have different SI and TI parameters and lie in various (opposite) positions in the SI/TI diagram (**Figure 3**). In **Figure 7**, 10 graphs are inset: depending on mentioned test sequence, resolution and used objective metric.

According to the experimental results and graphs, several conclusions can be pronounced:

1. The impact of chroma subsampling on the video quality is negligible: there is no difference between unsampled (4:4:4) and subsampled (4:2:2; 4:2:0). It follows that it is more useful and reasonable to use chroma subsampled: you can save up to 50% of the bandwidth by the same quality.
2. As we assumed the H.265/HEVC compression standard yields better compression efficiency than H.264/AVC compression standard—at the same resolution and bitrate, the compression quality of H.265/HEVC standard is better than H.264/AVC. The quality of both compression standards rises logarithmically with increasing bitrate—in low bitrates the quality grows faster than in high bitrates.
3. By comparing both codecs, it can be generally said that the bigger difference in quality is in lower bitrates—with increasing bitrate the quality of H.264/AVC codec approaches the H.265/HEVC codec.
4. The coding efficiency of H.265/HEVC standard is more visible in UHD resolution.
5. The effectiveness of compression depends on the types of test sequences. In consideration of measurements' results, we can say that sequences with smaller TI and SI, for instance, the "Bund Nightscape" and the "Construction Field," yield better quality in low bitrates than other sequences. Vice versa, the sequences with high motion as the "Runners" or

the "Marathon" yield worse quality in low bitrates. Individual category is sequences that contain many details, for instance, the "Fountain" sequence—this type of sequences has no so big difference between qualities in low and high bitrates, and they do not reach high quality in higher bitrates.

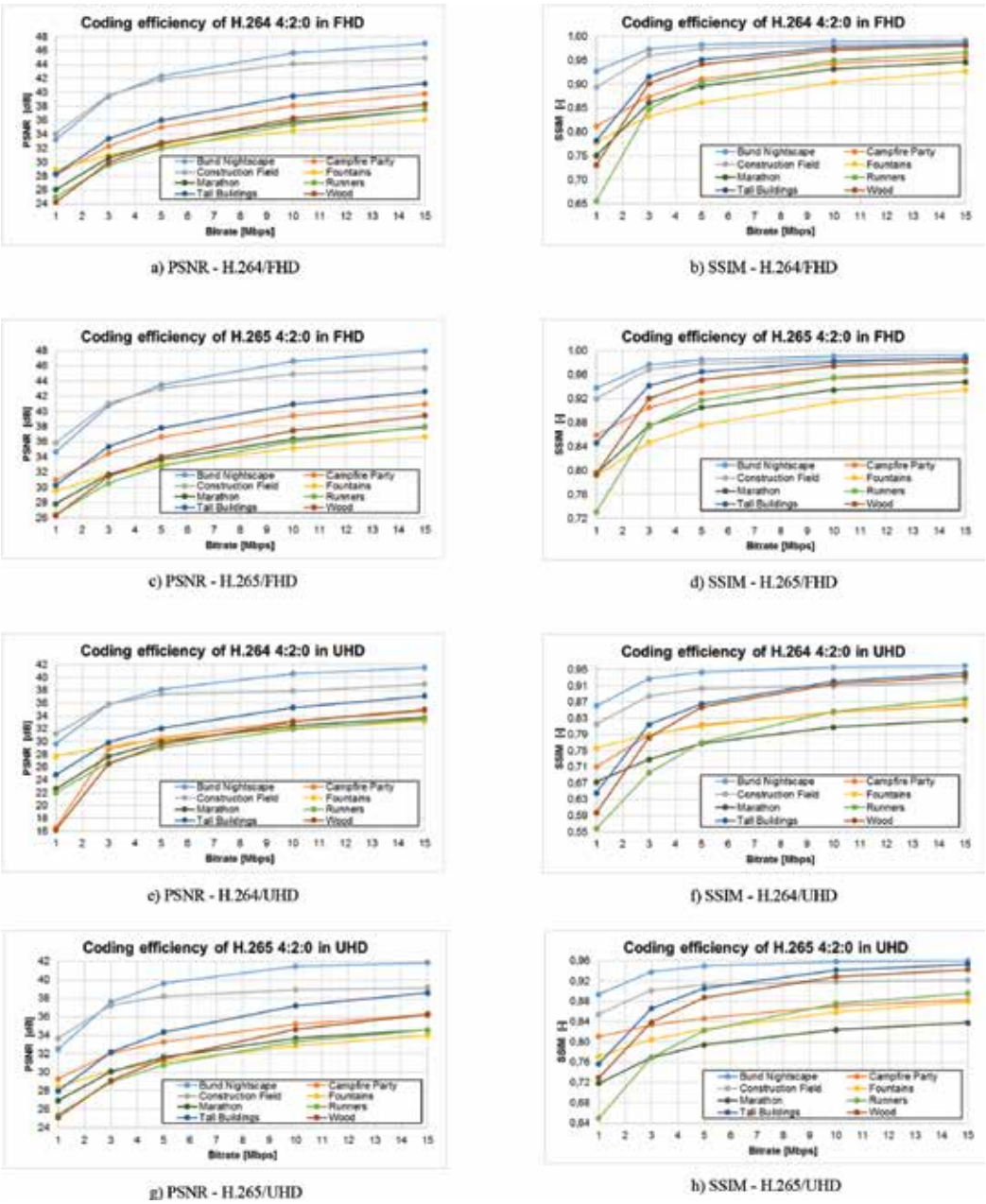

Figure 5. The ratio between video quality and bitrate of both compression standards of all test sequences for both resolutions.

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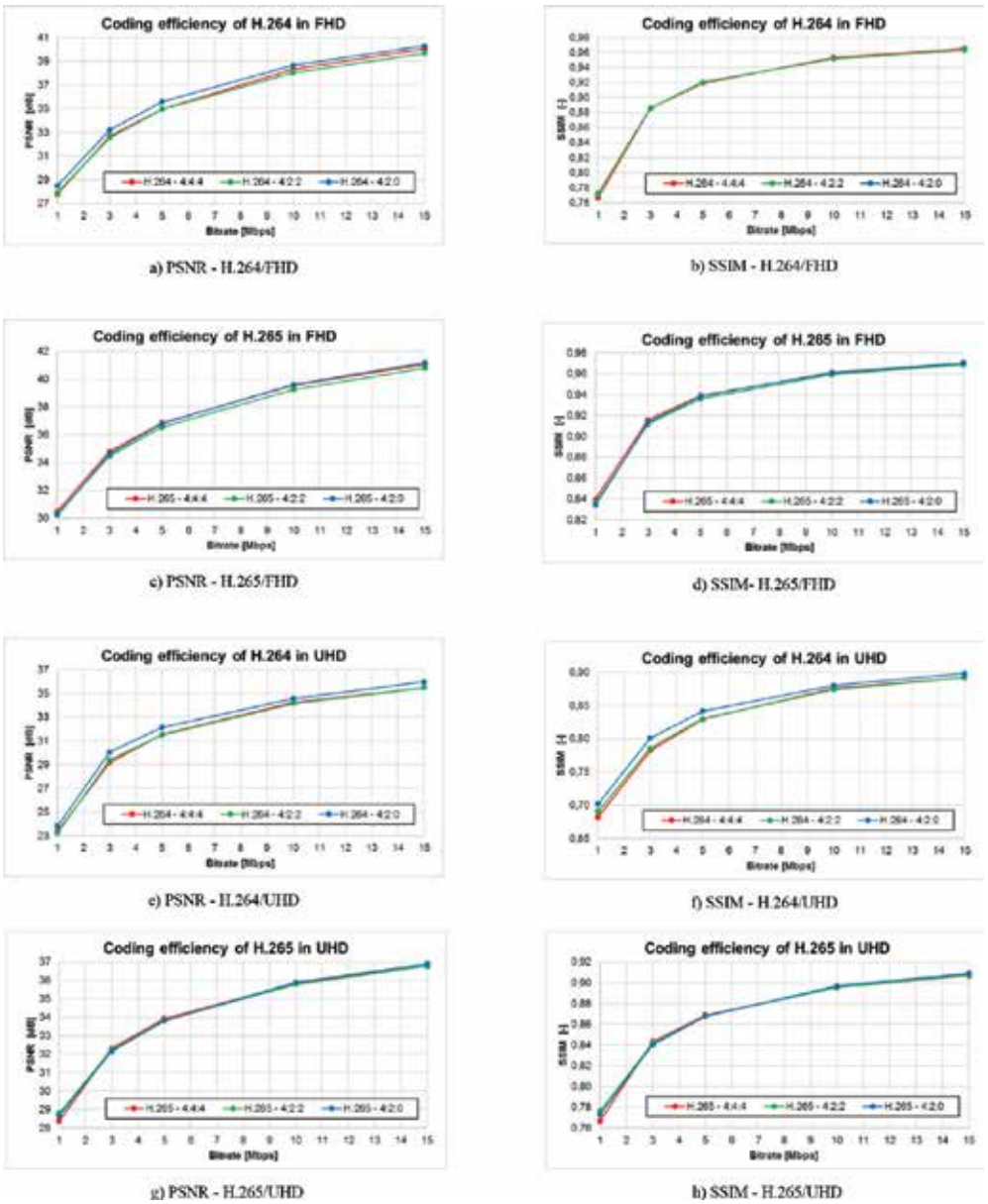
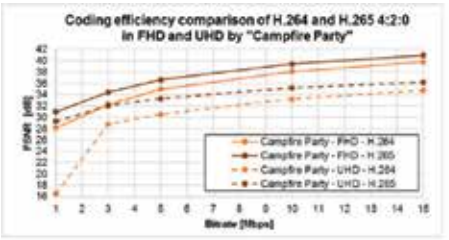


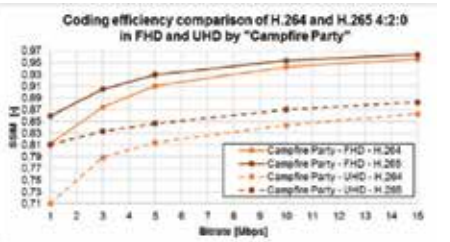
Figure 6. The impact of the chroma subsampling on the video quality of both compression standards of all test sequences for both resolutions.

8. Conclusion

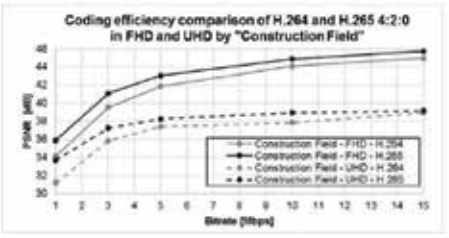
This paper dealt with the influence of chroma subsampling on video quality measured by objective metrics for H.264/AVC and H.265/HEVC compression standards. The evaluation was done for eight types of sequences with Full HD and Ultra HD resolutions depending on



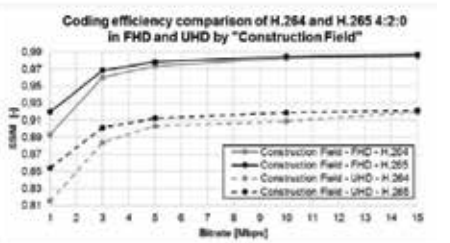
a) PSNR – Campfire Party



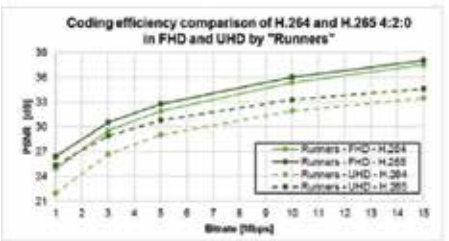
b) SSIM – Campfire Party



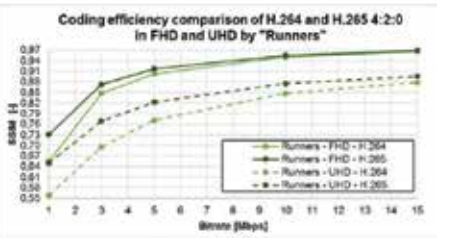
c) PSNR – Construction Field



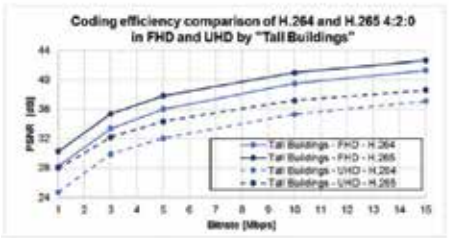
d) SSIM – Construction Field



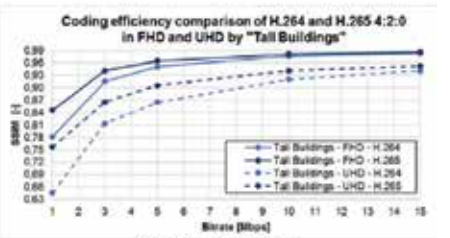
e) PSNR – Runners



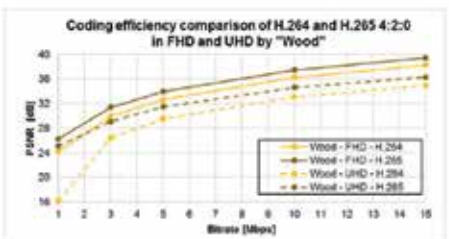
f) SSIM – Runners



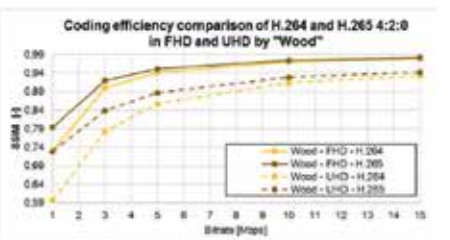
g) PSNR – Tall Buildings



h) SSIM – Tall Buildings



i) PSNR – Wood



j) SSIM – Wood

Figure 7.

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content. The experimental results showed that there is no impact of chroma subsampling on the video quality—there is no difference between unsampled (4:4:4) and subsampled (4:2:2; 4:2:0). According to the results, it can also be said that H.265/HEVC codec yields better compression efficiency than H.264/AVC, and the difference is more visible in UHD resolution. The bigger difference in quality is in lower bitrates—with increasing bitrate the quality of H.264/AVC codec approaches the H.265/HEVC codec.

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Author details

Miroslav Uhrina*, Juraj Bienik and Peter Kortis

*Address all correspondence to: miroslav.uhrina@fel.uniza.sk

Department of Multimedia and Information-Communication Technologies, Faculty of Electrical Engineering, University of Zilina, Univerzitna 1, Zilina, Slovakia

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Chapter 6

Mobile Probe for Cellular Network Coverage and Quality Measurement

David Vasicek, Martin Mikulec, Erik Gresak,
Filip Rezac and Erik Chromy

Additional information is available at the end of the chapter

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Abstract

This article describes a proposal of the probe application used for 2G–4G mobile network coverage and speech quality measurement. It is based on Android platform, most commonly used operation system for mobile phones. Measured results are visualized in the form of a map using GPS location. There are few tests available focusing on the applications that are most often used: test of the network coverage, speed of the websites loading, data rate test and voice quality test. The results are analyzed directly in the application and are also available over the web interface form. Individual results can be exported to standard output .csv, .json and .xml formats for further analysis.

Keywords: PSEQ, GSM, UMTS, LTE, mobile network measurement

1. Introduction

The last decades were in the name of development, improvement and expanding of telecommunication capabilities. Mobile networks are no exception, because they went through a gradual improvement and can be divided into several generations based on the used technologies and parameters.

These networks are characteristic by their users who require to use their services and devices on different places always expecting the adequate quality no matter on the current mobile network coverage or technology. By an appropriate quality signal, we can imagine when the item or in this case a service is perceived positively. It acts and works how it is supposed to. It is in the line with specifications which service producer advises and also with the customer demands and expectations.

However, the real coverage of mobile network is most of the time different from the ideal mathematical models and it is very hard to take into account all the factors that affect the spreading signal characteristics. Due to this fact, mobile operators use data from real measurements to make their models accurate. These measurements are realized using the special vehicles made for these situations and the measurement of the signal progress in a predetermined area. This method is very expensive and time consuming and thus opens the field for a cheaper alternative directly using the end user devices.

The role of our project has laid on the proposal and implementation of the mobile measuring probe using the open-source technologies. This probe collects location information, signal strength and speech quality in a given place and time for all commonly used networks from 2G to 4G while sending measured data to the central server, where the data are then analyzed and visualized using graphs and interactive maps. One of the main goals of this application was also performing individual and periodic remote measurements without any user interaction, in both the open areas and indoors.

2. Review of the current applications

Nowadays, there are a lot of tools available for the mobile network monitoring and most of them can be found on the Android platform market. Each of this application is different, but the goal is the same—trying to get the information and parameters from the mobile network. Most of these apps also allow a preview about the LTE sites, using the plotting graphs and maps, or are able to export the results.

The available downloadable applications on the Google Play Store are G-NetTrack [1], NetworkSignal Info [2], Network Cell Info [3] and others. However, few of them are able to offer other measuring tools such as downloading speed test, speech quality test and more. For these purposes, there is a need to download a secondary application which discourages users from regular use. Therefore, there was a request to develop and create an application

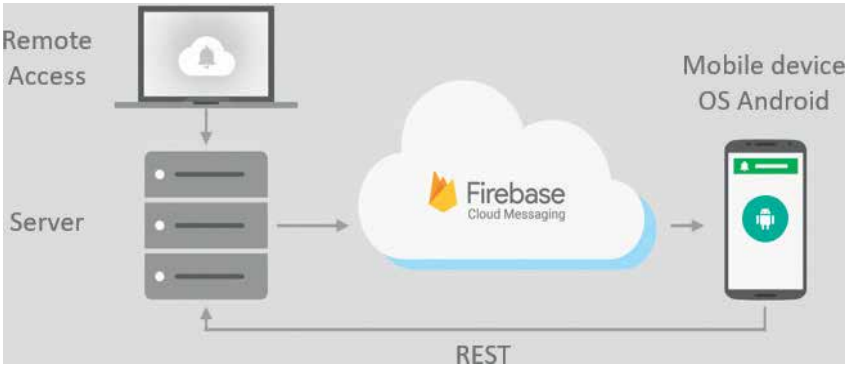

Figure 1. Mobile probe working diagram.

that would unite available measuring tools on the market into one application, creating a full-fledged tool for comprehensive testing of mobile networks.

Developed mobile probe application was created for OS Android from version 4.0.3 IceCreamSandwich to 6.0 Marshmallow and was tested mainly on Samsung phones with Android TouchWiz and Google Nexus phones with pure android. Following chapters describe the algorithms and methods used for the selective tests, and the technology for data visualization is also mentioned.

A diagram of the mobile probe functionality is shown in **Figure 1**.

3. Available in-app tests

It has been mentioned above that besides the testing of a network quality parameters, the mobile probe is able to run the speed test of loading web pages, data rate test and voice quality test. Each of these tests can be run once or repeatedly in a user-specified interval.

3.1. Coverage test

The main goal of this test is to get the *gettinf* parameters from 2G, 3G and 4G networks. From the available information, in parameters point of view, we are able to divide the mobile networks into two categories: non-LTE networks (GSM, EDGE, UMTS, HSPA, and HSPAP) and LTE networks. The non-LTE networks provide mainly RSSI, BER, ASU, EnodeB, TAC, LAC, Cell-ID and operator information parameters, and from the LTE, we can get RSRP, RSRQ and SINR. Most of these parameters are obtained from the *TelephonyManager* android class. This one allows the access to information about telephone services.

Each of the obtained parameters is dependent on the GPS position. Without this information, the whole test is giving inaccurate information. Because of the functionality of the mobile probe even in the indoor mode, where the GPS is often unavailable, there is a feature to insert the coordinates manually or clicking on the map.

3.2. Web page load speed test

The purpose of this test is the measuring of a loading speed of the web pages, where the application collects primarily the size of the downloaded data, how long they are being loaded, time interval between the download request and the beginning of downloading itself, the number of downloaded files and the number of displayed files on one page.

This test uses a developed *WebView* class, which is a fully functional web client, who is reading the website, and generates the measurements in the same time. The measurements are realized by overloading the *WebView* class methods and maintaining a list of all resources on the client when downloading the website. The records are later used to determine the size of the data on the page. After completion of the loading process, the timer is stopped automatically by calling an overloading *onPageFinished* method.

3.3. Data speed test/FTP test

One of the main tests from the list also includes a download speed tests. There is a need to obtain objective measurements, and it can be done, for example, with a file transfer test between the client and FTP server. This measurement should conform to the recommendations set out in the specification ETSI TR 102 678 [4]. According to this specification, it is necessary to measure a fixed transmission time when the downloading and uploading are on progress. This time is fixed for both directions and is set to 10 seconds. After this time interval, data transfer is analyzed, calculating the transmission rate. This test is able to determine the download data speed, upload data speed, response time and possibly even other additional parameters that are useful in determining the quality of mobile network services.

Additional parameters include minimum and maximum speed data transfer in both directions and whose values were obtained by subtracting the amount of the data transferred every second during the transmission time and access to the FTP server, that is, the time between signing and starting the actual transfer.

3.4. Voice quality test

The speech quality evaluation is measured by the Mean Opinion Score (MOS), which is a five-degree scale developed by ITU-T [5]. This scale is shown in **Figure 2**. The objective methods are trying to be as precise as possible to gain adequate MOS value as it would be obtained by subjective methods with sufficient number of participants for adequate statistical analysis. The objective methods are divided to intrusive and nonintrusive methods. The intrusive methods use the original sound sample as it has entered the communication channel and compare it with the degraded signal in the output. One of the most known intrusive methods is the Perceptual Evaluation of Speech Quality (PESQ) method according to ITU-T P.862 [6, 7].

Due to the fact that the PESQ algorithm is currently widely used, we decided to use this algorithm as the keystone of our measurement. The intrusive method is used to determine the quality of the speech, when the test system compares the original signal $x(t)$ with the degraded signal $y(t)$ taken at the other end of the transmission chain. Subsequently, reached

Figure 2. Five-degree scale of MOS.

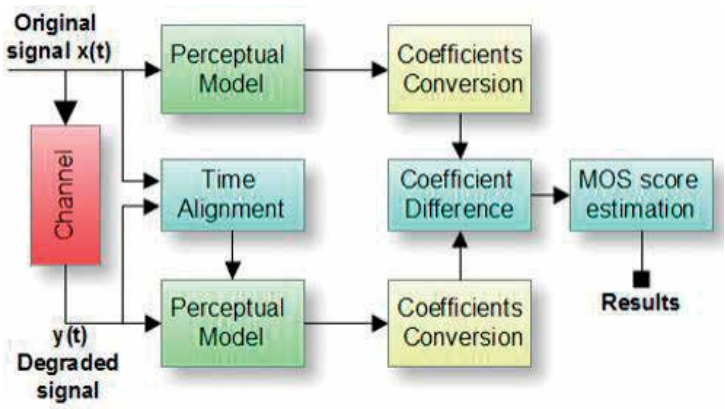

Figure 3. Basic diagram of PESQ algorithm.

values are evaluated in MOS-PESQ scale and then transferred using complementary recommendation P.862.1 on the values of the MOS-LQO scale, as shown in **Figure 3** [7, 8].

The PESQ method first computes several series of delays between the original and degraded signals, where each of these series corresponds to one interval of signal. The delay for each interval is different because of ensuring proper functioning of the PESQ algorithm. For each interval, start point and end point of time are also determined. Based on these series of delays, the PESQ algorithm compares the original and degraded signals using the perceptual model. The resulting PESQ-MOS score is expressed as a range of values from -0.5 to 4.5. This score has to be converted to more accurate scope, more accurate for human subjective evaluation. Therefore, it is necessary to use complementary ITU-T P.862.1, which will provide scale transfer from MOS-PESQ to MOS-LQO. Scale MOS-LQO provides a range of values from 1 to 5. Conversion from PESQ-MOS to MOS-LQO is defined by Eq. (1) [6, 7, 9].

$$y = 0.999 + \frac{4.999 - 0.999}{1 + e^{-1.4945x + 4.6607}}, \tag{1}$$

where the variable x represents the value of the MOS-PESQ scale and y represents MOS-LQO score. Inverse score (MOS-PESQ) from LQO is shown in Eq. (2) [7].

$$x = \frac{4.6607 - \ln\left(\frac{4.999 - y}{y - 4.999}\right)}{1.4945}. \tag{2}$$

4. Remote access

From the need for remote monitoring of individual devices, a Firebase Cloud Messaging (FCM) service [10], formerly known as Google Cloud Messaging (GCM), has been implemented into our mobile probe. This service allows a remote server to run individual tests and services in different devices using incoming notifications to the device. This is achieved

by registration of each mobile device by its unique identifier and generating a security token. Each registered device is then allowed to run individual tests from a remote server to either once or periodically with a specified interval.

In the mobile device, FCM works as a background service without a graphical user interface (GUI) and it allows to run all the services and tests without user interaction and without need of having the application open.

5. Result visualization

Collections of the measured results from individual probes are stored on the central server using the SQL database. From there, the data can be further processed and analyzed for the need of the visualization on the individual probes or for the production of statistics from a selected data samples. These data are separated based on different tests, and there is also a filter option available. The synchronization of data with central server is realized using the REST data-oriented interface [11].

For easier overview of the acquired data, a graphical interface maps are built using a web-based mapping applications *Leaflet*/*OpenLayers*, which provide a complete picture of the real network levels and signal quality of mobile cells. Each level of that signal is subsequently separated by individual color markers and allows to reveal the blind spots of the received signal in the individual areas.

The measured results in each test are displayed in a clear list and divided into categories according to individual tests that were conducted. Each displayed test is interactively active and allows the user to display a GPS position from which the test has been taken.

Map data on the mobile application are realized by the *OpenStreetMap* licensed under the Open Database License (ODbL) [12]. These maps show all the results of individual measurements graphically divided according to the various tests and by the various levels of the received signal.

6. Conclusion

From scientific point of view, this project does not come with new thoughts and ideas, but it comes with the very progressive implementation on the field of the measuring of quality and coverage on the mobile networks. Also, thanks to our developed mobile probe, the mobile operators can improve their services based on the real data measuring and mobile subscribers are encouraged to run these measurements to increase the customer satisfaction with the improved services as well. Our proposed solution brings time- and cost-effective alternative for mobile service providers with the possibility of actively or passively engaging their customers in improving services. Although this project is still being developed, it is already able to be fully deployed in the real world.

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Author details

David Vasicek[1]*, Martin Mikulec[1], Erik Gresak[1], Filip Rezac[1] and Erik Chromy[2]

*Address all correspondence to: david.vasicek1@vsb.cz

1 Department of Telecommunications, Faculty of Electrical Engineering and Computer Science, VSB-Technical University of Ostrava, Ostrava, Czech Republic

2 Institute of Telecommunications, Slovak University of Technology in Bratislava, Bratislava, Slovak Republic

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Chapter 7

Employing Monitoring System to Analyze Incidents in Computer Network

Lukáš Macura, Jan Rozhon and Jerry Chun-Wei Lin

Additional information is available at the end of the chapter

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Abstract

Today, network technologies can handle throughputs or up to 100 Gbps, transporting 200 million packets per second on a single link. Such high bandwidths impact network flow analysis and as a result require significantly more powerful hardware. Methods used today concentrate mainly on analyses of data flows and patterns. It is nearly impossible to actively look for anomalies in network packets and flows. A small amount of change of monitoring patterns could result in big increase in potentially false positive incidents. This paper focuses on multi-criteria analyses of systems generated data in order to predict incidents. We prove that system generated monitoring data are an appropriate source to analyze and allow for much more focused and less computationally intensive monitoring operations. By using appropriate mathematical methods to analyze stored data, it is possible to obtain useful information. During our work, some interesting anomalies in networks were found by utilizing simple data correlations using monitoring system Zabbix. Afterwards, we prepared and preprocessed data to classify servers and hosts by their behavior. We concluded that it is possible to say that deeper analysis is possible thanks to Zabbix monitoring system and its features like Open-Source core, documented API and SQL backend for data. The result of this work is a new approach to analysis containing algorithms which allow to identify significant items in monitoring system.

Keywords: monitoring system, computer network, data analysis, neural networks, Monda

1. Introduction

This paper explains new and efficient method to analyze and pre-process monitoring systems data for advanced analysis using neural networks and machine learning methods. Well-trained

neural network can predict known and unknown types of incidents with high probability, and warn administrators before these occur. Other approaches exist and they are based on artificial intelligence that can be used for this purpose, for example, a Markovian model-based solution is described in [1, 2]. A swarm intelligence-based solution is presented in [3, 4]. It is also possible to identify the cause of the problem, for example, when indicator (e.g. free disk space) is out of range but the actual cause is elsewhere (the attack on a specific service). The big advantage of using network and system monitoring tools is that the basic correlation rules are already in monitoring systems as these are typically setup to inform administrators about abnormal behavior that could impact system availability.

There are many different monitoring systems. All the principles written here are theoretically applicable to any monitoring tool, however, we selected Zabbix, an Open-Source project. The main selection reason is the proper organization of internal data and history in this system, the possibility of in-depth, focused and automated analyses directly using SQL and open API.

We created an Open-Source tool Monda. Its primary purpose is a selection and pre-processing of Zabbix data allowing use of more sophisticated mathematical methods and procedures. The project is hosted on Github.com server and is accessible to the entire community. The project currently has 6200 lines of source code. It has been designed for team collaboration and allows adding of new analyses.

2. Methods

We can say that if we want to operate a network uninterrupted for a long term, a monitoring system is a crucial part of the successful way to accomplish this. We need to monitor and track most of network equipment and servers to have a good footprint of network. The mere recording of network logs is important, but without monitoring it is ineffective. It can occur very often that some data source (from some security probe) is missing due to failure. If we do not monitor this, network seems to be without problems even if there is a security incident on the background.

There is yet another reason for network monitoring. If an attacker knows where security device is located and he knows its vulnerabilities, he can focus first attack directly there. If this attack is successful, security device is not functioning properly and there is no monitoring enabled, administrator cannot be informed about this and next attacks.

There are software and hardware platforms that are able to detect anomalies in network traffic by inspecting packets or streams [5]. Similarly, there are platforms which are able to analyze the log files [6]. Their disadvantage is mostly narrow focus. Even if information from flows is very important, it is usually not enough for deeper analysis because there is no further information, such as load for each server or network elements. Modern devices are able to classify traffic based on the days of the week and time of day to respect common usage in networks based on work hours and work days. It is even possible to use special probes as source of data for monitoring systems like VoIP attack analysis [7–9].

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3. State of the art

There is a lot of tools to identify and classify network incidents but there is no tool based on data from monitoring system. We choose Zabbix and data from Silesian University to do further analysis of data because of their availability and because of Zabbix features.

Generally, the security must be carried as close to the potential problem as possible to ensure the best possible efficiency of the security measures. The local network is required to employ properly set up measures against spoof attacks and enable general ban of unsafe services that are not used. Well-configured network should not allow trivial attacks like faking MAC addresses, IP addresses or ARP. As an opposite, in carrier level network, there has to be only limited amount of security measures. A typical example of the attacks on the carrier level where the attacks to some news sites in Czech Republic. Even though the stream of data flows across most of the big operators, the actual protection against attacks must occur on server itself.

Our goal was to identify interesting data from monitoring system and use them for further analysis.

3.1. Zabbix

Zabbix [12] is very common monitoring system developed as Open-Source. It supports variety of data inputs and can do very flexible operations over these data. In addition, it is very flexible report tool. Its internal design varies from other monitoring tools. It is suitable for further analysis because all data are available in SQL. Changes in configuration are respected automatically and restart of server is not needed to apply them. Most of data are available even over JSON API.

Zabbix key features:

- It is possible to monitor almost everything (due to vast protocols support and external scripting).
- Configuration and data in SQL.
- Web application monitoring.
- It scales from small setup to huge installations.
- Power: it can monitor thousands of new values per seconds.
- Supports user acknowledgments to problems.
- API for automatized analysis.

4. Design of the system

Mathematical model is based on common principles but for further reading and understanding we used glue between mathematical model and monitoring system. Basic rule for any

analysis is correct selection of data. There is a lot of data in monitoring system. Our installation of Zabbix on Silesian University has approximately 1 TB of data. We cannot use all data for analysis and it is not even necessary. It is enough to understand the way how data are fetched and stored and how to do basic statistical analysis based these data. After this step, called pre-processing, we can do further analysis.

4.1. Anomaly

To be able to search for an anomaly, we have to define it. This can be tricky. If anomaly is defined too strictly, we can never find it. On the opposite side, too widely defined anomaly will generate a lot of events and computations. It is possible to use trigger priority and trigger acknowledgment for this. For example, we can look into problems with priority higher than warning which were not acknowledged by users.

There are six trigger priorities in Zabbix.

- Not classified—for events which do not affect network but we want to know about it.
- Information—for events which do not affect network but we want to know about it.
- Warning—for events which can affect network.
- Average—for events which effectively affect network.
- High—for events which can harm network.
- Disaster—for events which has to be solved as soon as possible and have big impact on network.

4.1.1. Time window

We have to define Time Window before searching for any anomaly. Some anomalies can last for fraction of second, other can be several days long. In addition, some processes in network are specific for some hour in day or day in week. We have to take this into account. For example, regular backup process can affect entire analysis if we do not consider it as regular process. This work primarily focuses on anomalies which have longer time range, it means several minutes and hours. This is due to the fact that monitoring system is not suitable for very short incidents due to the fact that data are fetched in regular intervals which are at minimum 30 s but in most cases it can be several minutes and data inside these intervals are summarized.

4.1.2. Item

In conjunction with Time Window, it is appropriate to analyze items separately. For example, CPU load on server can be a useful indicator what happens on server. It can have some specific features like recurrence, statistical features and some statistical associations in data [10]. Simple prediction of value or searching anomalies without external data is not efficient. Zabbix can do simple value predictions using linear extrapolation but this will work only for

small amount of items due to their features. Zabbix can even evaluate some trigger based on simple mathematical formula and values in history. Again, it is not suitable for further analysis without external data. For example, CPU load can vary depending on server usage and it is not predictable.

4.1.3. Host

After simple analysis of Item History it is needed to find their correlations within host. Typical scenario is dependency between CPU usage, disk load and network interface utilization. This combination will be relatively unique for some kinds of applications or servers.

4.1.4. Correlation with events

Previous analyses were independent on events. Item and Host analysis without events did not respect overall network functionality, but only one Item/Host values in history. Event time and value is very good source of information because we can focus on specific data, time and value which caused event to raise.

4.1.5. Correlation with acknowledgments

Event is based on mathematical formula and data from history of Items. There is no human feedback. There can be some false-negatives or false-positives due to badly configured triggers. Acknowledgment is good for fine tuning analysis and to filter such false states because human (in most situation network administrator) manually tag given event as real problem or false state.

5. Algorithms

5.1. Data selection

To be able to focus on and work with huge amount of data, pre-processing is needed. This part of analysis is crucial. It would not be possible to do complex analysis over all data in monitoring system. And it would not lead to good results. Even for future, pre-processing part will be primary place for any optimization and improvements. Mathematical principles and formulas are strict and their algorithms are known and well optimized. But pre-processing is data specific and has to be driven with focus to data features. There is a lot of data inside monitoring system and there are many kinds of it. It can be number, specifying state of interface which is integer from 0 to 10, it can be float as processor load or integer which saves actual disk free space in bytes. Small change in one item is not important but same change in other item can mean big problem in network.

From this reason we have made our own Open-Source software Monda, hosted on GitHub, which is highly configurable and which does pre-processing part (but even more). Our goal was to create framework and common environment where every user can create his own

version of pre-processing strategies based on his setup. After we created and tested Monda, it became possible to do further analysis of data focused to Time Window, Host or network process. One big advantage of this software is that it can be automated.

Primary goal of our work is in innovative approach to selection and pre-processing of data using algorithms above. We used dimensionless quantity *LOI* (Level Of Interest), which is integer. Bigger LOI means more interesting data. Algorithms and formulas used will be explained later. Further mathematical analysis is based on LOI. When doing some complex computation, objects with highest LOI are selected first. If there is enough CPU, RAM and disk size, it is theoretically possible to analyze all data inside or all data for specific Time Window only. But LOI will do preview of data inside Zabbix and selects most interesting data for further analysis.

5.2. Algorithms and data structures

Data in Monda are structured into Time Windows and Item statistics, see **Figure 1**. Basic feature of Monda is that data in Zabbix are untouched. So computation is based in Zabbix database and results from it are saved into Monda database. Monda database only describes data in Zabbix and mark them with adequate LOI.

As shown in **Figure 1**, Item that seems to be important in one Time Window can be uninteresting in another window. Typical example is free disk space. In most Time Windows, there is no big change of it. But in specific window where some kind of attack affected it, change can be bigger and Item can be interesting at this time. Algorithm used in pre-processing will prefer combination of Item and Time Window if there are more changes, see below.

Similar to Time Windows, there can be interesting and uninteresting one. During work hours, there is a lot of changes in network metrics and these windows will be preferred. On the opposite side, night hours can be skipped because there were no interesting processes.

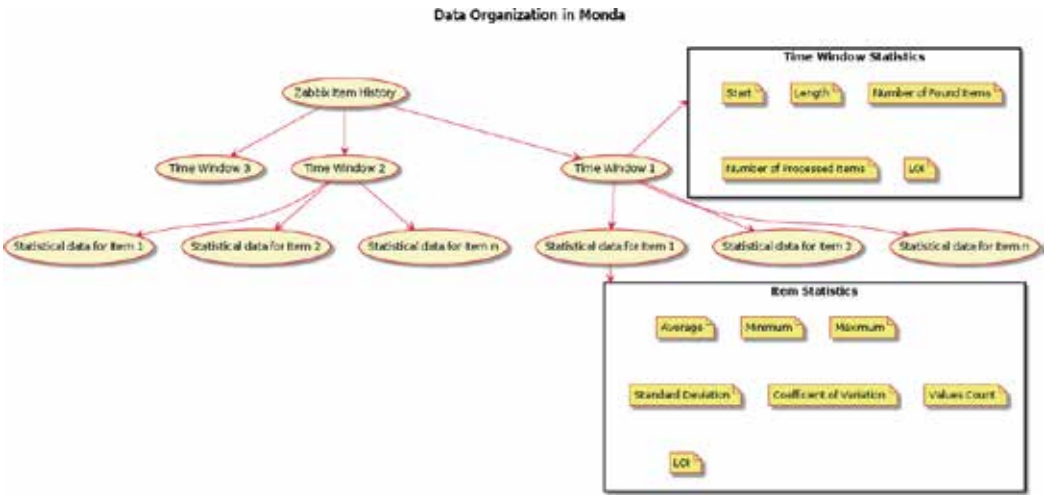

Figure 1. Organization of data in Monda.

Step-by-step algorithms follows.

1. *Create Time Windows:* Monda creates Time Windows either automatically or based on user preferences. By default, windows with length 1 hour, 1 day and 1 week are created. Time Windows are hierarchical. Week window is parent of 7 single-day windows and each of day window is parent of 24 single-hour windows. But even when there is hierarchical structure, each window is computed separately.
2. *Item Statistics in Time Window:* Item statistics is set of data which describes Item history in given window. There is information about average, minimum, maximum, standard deviation, number of values, coefficient of variation and LOI. Depending on Item source, data can vary very much. For example, processor load can be number from 0 to 100%, size of free disk space can be bytes or terabytes. Situation is even more complex because some Item's absolute change can have big impact on network while same change on other Item has no impact at all. Even more, absolute value can be big but a small change can have impact too. This is typical with counter of errors on interface. Due to some historical reason, there can be thousands of CRC errors on interface but it does not increase in time. But when it increases, even a small change should be taken into account. Next problem which is related to the fact how monitoring system works is that some items can be fetched in 30 s interval but other in 10 min interval and even more. While we need to fetch CPU usage each 30 s, for disk usage it is enough to fetch it each 30 min.

At this time, algorithm works only with numerical data in Zabbix. It ignores everything else than integer or float in history. It is possible that this will change in next versions. Even string processing can be useful task to take into account. Next improvement would be to better describe data and meta information of Items. It could be possible to mark some data as more important directly in Zabbix and instruct Monda to increase LOI of Item even if absolute change of it is small.

Item statistics:

- Minimum $min(x)$,
- Maximum $max(x)$,
- Mean $avg(x)$,

$$\mu = \frac{1}{count} \cdot \sum_{i=1}^{count} x_i \tag{1}$$

- Standard deviation $stddev(x)$,

$$\sigma = \sqrt{\frac{1}{count} \cdot \sum_{i=1}^{count} (x_i - \mu)^2} \tag{2}$$

- Coefficient of variation CV,

$$CV = \frac{\sigma}{\mu} \tag{3}$$

- Number of values *count*,
- Level of interest LOI_{is}

$$LOI_{is} = 100 \cdot \frac{CV}{CV_{max}} \tag{4}$$

CV_{max} is configurable with default equal to 100.

The example of the command for the windows with IDs 47,245 and 46,915 looks like follows:

```
$ monda is:show -w 47,245,46,915 --itemids 1,2.
```

This command yields, for example, the following data (**Table 1**):

Itemid	**1**	**2**
min	0	0
max	1,069,274	48
avg	743	0.03
stddev	28,177	1.28
loi	546	484
cnt	1440	1440
hostid	1	2
cv	37	33

Table 1. Item statistics example.

3. *Time Windows*: For all Time Windows, Item statistics are computed. It means that for each Time Window, Zabbix history is searched, analyzed and computed for all Items found inside. Some items are automatically removed at this part of analysis because there is not enough data for them in given window. For example, for item "disk free bytes" which is fetched every 20 min there is not enough data in 1 hour window (three values) to do any usable analysis over it.

There are basic statistics computed for each Time Window, see below. All constants are configurable by Monda. This is first place where data are reduced. Useless data (items with small changes, items without history or items with small standard deviation) are not copied into Monda database (**Table 2**).

Time Window Statistics:

- found: overall number of items found in window
- lowcnt: items with low number of values
- lowavg: items with mean which is near to zero

Length	1 day	1 hour
found	35,863	35,751
processed	4593	1079
ratio	12%	3%
ignored	31,269	34,671
lowstddev	29,281	30,266
lowavg	779	140
lowcnt	105	3794
lowcv	1101	468

Table 2. Time windows statistics example.

- lowstddev: items with small standard deviation
- lowcv: items with small coefficient of variation
- avg.(count): average count of history data per item
- avg.(CV): mean of coefficient of variation
- Level of Interest LOI_{tw} (1)

$$LOI_{tw} = 100\, avg(count)\, avg(CV) \frac{processed}{found} \tag{5}$$

4. *Hosts*: Just after Time Window statistics, Host statistics are computed. Inside each Time Window, all Hosts are found, Items are categorized for them and after this, statistics are computed.

Host in Zabbix can be any network device. Herein statistics makes a glue between Items and Hosts so it is possible to do Host specific computations in Time Windows. Example of Host statistics is in **Table 3**.

5. *Host statistics:*

- Number of Items found for Host in Time Window *items*
- Number of History rows for Host in Time Window *cnt*
- Level of Interest LOI_{hs}

$$LOI_{hs} = 100 \cdot \frac{count}{count_{max}} \tag{6}$$

The example of the command for the windows with IDs 46,965 and 47,241 looks like follows:

```
$ monda hs:show -w 46,965,47,241 --hostids 1,2.
```

This command yields, for example, the following data:

hostid	windowid	count	items	loi	type
1	46,965	8956	54	185	switch
2	47,241	1802	24	100	server

Table 3. Host statistics example.

6. *LOI update for all Time Windows*: As mentioned above, Zabbix has more information inside than only history. There are Events and Triggers. LOI for Time Windows are updated to respect this fact. More Events in Time Window lead to bigger LOI.

- Depending on Event time, LOI is increased for each Time Window affected (parameter *ec_item_increment_loi*)
- Depending on Item(s) which caused Event, LOI is increased for each Item (parameter *ec_window_increment_loi*)
- Depending on Hosts where Event was found, LOI is increased for Host (parameter *ec_host_increment_loi*)

7. *Correlation Statistics*: After marking Items and Time Windows with Loi, correlations are computed. From the principle described above, most interesting correlations are computed. It is not possible to compute all of them because combination of all Items is wide. Example of such statistics can be found in **Table 4**. There are two kinds of correlations to compute. One is for correlation between Items in specific Time Window and correlation of same Item in different Time Windows. First type is to analyze behavior of different values in same time while second is to analyze behavior of Item in different times. For example, to compare disk space usage in same hours of day.

windowid1	47,470	47,443	46,960
windowid2	4747	47,443	46,979
itemid1	server:cpu[user]	Switch:Ifln[“125”]	Server:cpu[iowait]
itemid2	Server:cpu[iowait]	Switch:IfOut[“77”]	Server:cpu[iowait]
corr	0.97	0.93	0.76
cnt	60	141	60
loi	155	94	398

Table 4. Correlation statistics example.

Correlation does not imply causality. But it is not important at this phase of analysis. Most important to know is if two Items correlated in Time Window and if so, how much significant this correlation was.

- Correlation within same Time Window

More Items are correlated in same Time Window. For example, how network interface load correlated with disk load at given Time Window.

- Correlation within same hour of day

It is common that correlations can occur even between different Time Windows and same Item. For example, there can be significant correlation of disk load on backup server at backup hours each day. Similar correlations can be found for weekly backups in given day of week. Instead of random processes which occurs in Time Windows, these correlations represent in most situations recurrent operations in network.

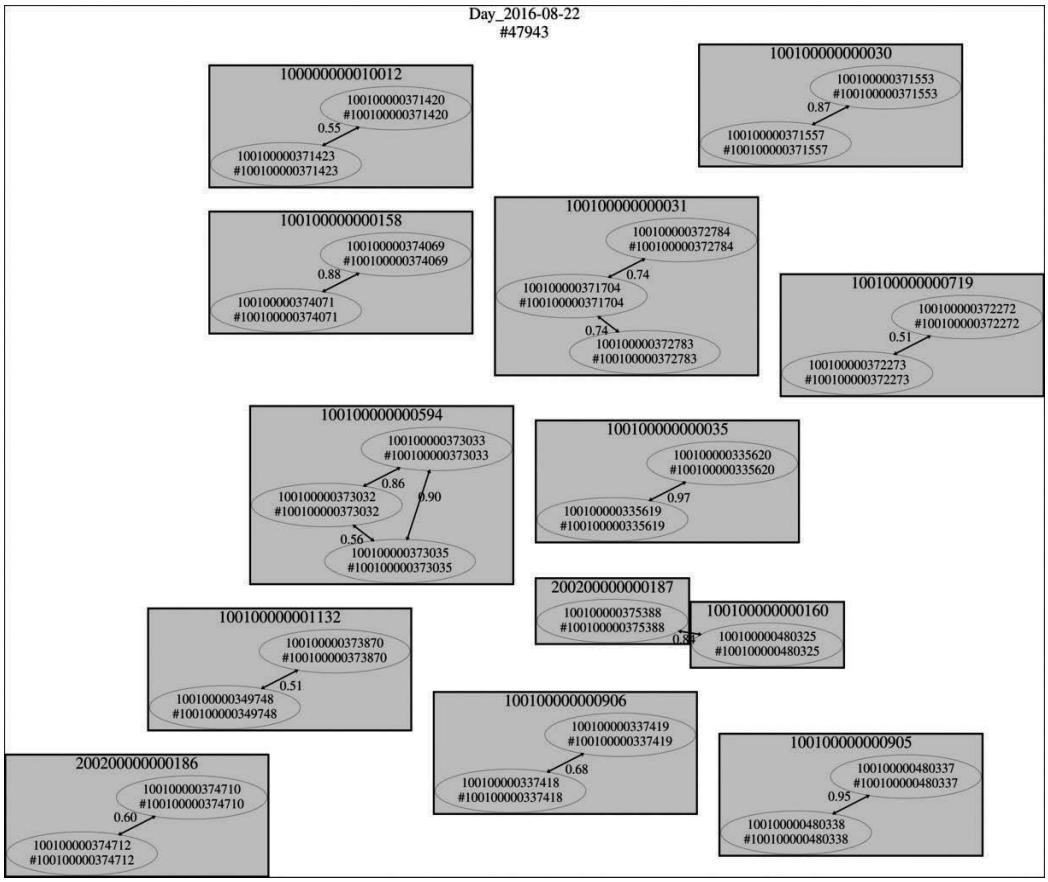

Figure 2. Correlations map: Servers.

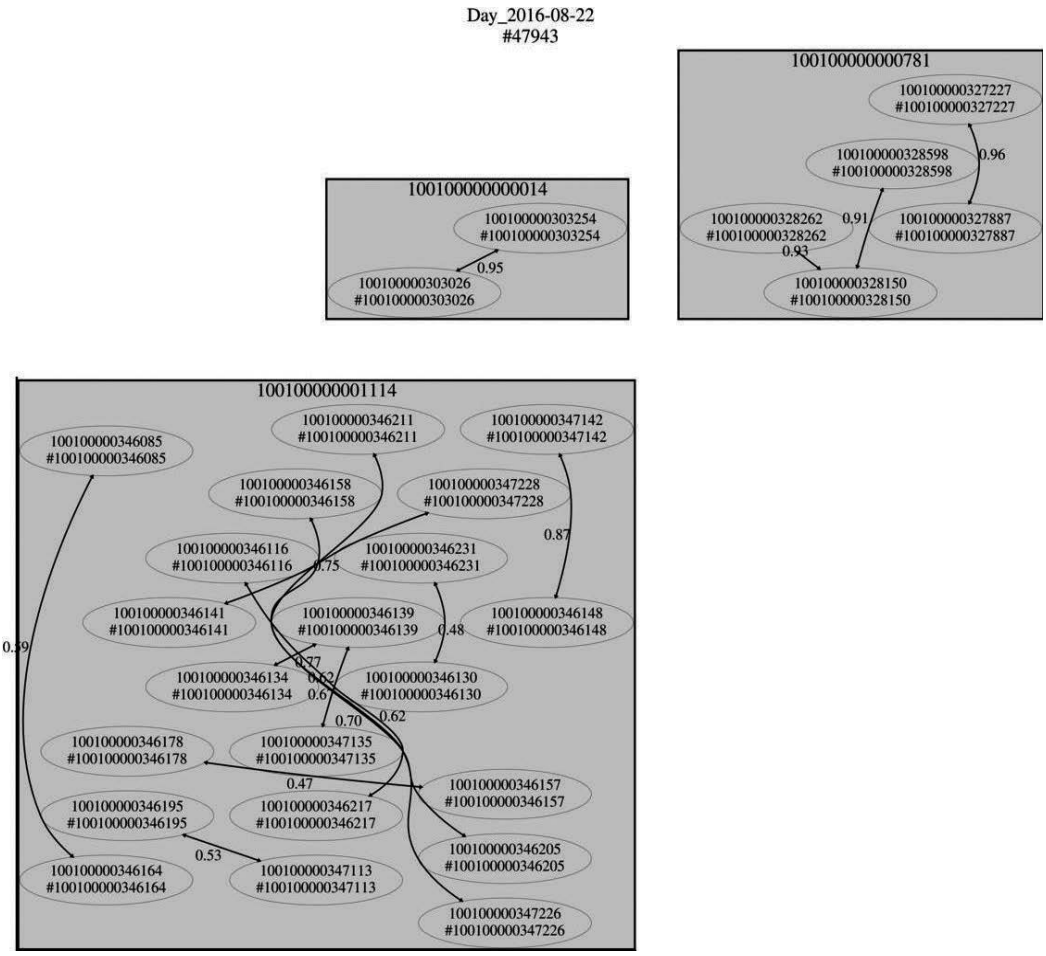

Figure 3. Correlations map: Switches.

- Correlation statistics
  - Number of values found for given correlation *cnt*
  - Pearson correlation coefficient *corr* which is from interval − 1 to 1
  - Level of Interest LOI_{hs}

$$LOI_{ic} = |corr| \cdot count_{w} \tag{7}$$

while $count_{w}$ is number of next items which correlated in same time.

The example of the command for the windows with IDs 46,965 and 47,241 looks like follows:

```
$ monda ic:show -w 46,965,47,241 --itemids 1,2.
```

This command yields, for example, the following data:

5.3. Results of the algorithm

Example of map, created by applying algorithm on data of Silesian University is depicted in **Figure 2**, which shows correlation between servers and their items. Rectangles represents servers and ellipses their Items. Connectors between them represent correlation coefficient. Data are anonymized for security reasons but correlations are visible. Next fact which is obvious is that more Items correlate together.

Next example is correlation map of network switch and its ports, see **Figure 3**. Different ports correlate between each other according to network throughput. Switches are represented as rectangles, load on their ports are ellipses. Connectors are correlation between loads.

6. Monda

Monda [11] was designed and coded from scratch. It was designed to do most of the computations directly in SQL. This was crucial to speed up analysis. The result of the analysis is stored back to SQL tables, so it is possible to do next quick operation within it. Zabbix server was configured not to delete any data. Instead of deleting history data it creates partitions of SQL tables in regular intervals.

Monda is used as a tool which concentrates to the significant amount of data in Zabbix database and tries to find most interesting values and windows automatically. As mentioned, it is not possible to do a complete analysis with overall data inside in real time. And in fact, it is not needed. A lot of data in monitoring system are not interesting.

Monda never copies data from Zabbix. Instead of it, it uses algorithms and procedures which operate inside data and copy statistical results into Monda database. At this time, Monda has approximately 6200 rows of code.

Overall design rule was not to affect Zabbix server availability or performance. Zabbix uses its tables very often and utilizes SQL server by itself. From this reason, it was crucial to take care of all Monda operations to work in most situations in idle time of Zabbix server. Next, it was needed to set SQL timeout for Monda queries. If Monda analysis takes more than 10 min per query, it stops automatically.

7. Conclusion

Interesting results were found during analysis. A new approach to identify network incidents was invented. We created software Monda which is Open-Source, and it can be used by anybody for subsequent kinds of analysis in Zabbix. Verification of methods was done on Silesian University data stored in the monitoring database.

7.1. General results

Data in monitoring system are interesting for subsequent analysis. Even if it is relatively complicated to choose right data and right intervals, data are suitable for prediction of some incidents. Monda can do pre-processing part very quickly and an effective way directly within SQL server. Anybody can write its analysis module to focus on specific incident or time. Algorithms used here are mainly based on logical assumptions which are derived from knowledge of monitoring system and its data.

Next assumption is that to do better analysis and prediction of incidents, the monitoring system must have more inputs about incidents on the network. In other words, more data related to security and statistics of systems, better analysis and prediction of incidents.

7.2. Future improvements

More information about stored data and their source means better pre-processing of data. One of the improvements could be a manual description of Items inside Zabbix so pre-processor could know right ranges for given Items.

Next, it would be nice if Zabbix could do data approximation on historical data. Zabbix deletes data from history after configured amount of days and computes trends from it. So we can see minimum, maximum and average in hour intervals. If Zabbix uses approximation function, it is possible to describe data at summarized intervals better.

It is possible to use SOM in future for better fingerprinting of Hosts. But it needs more investigations and more data of separated Zabbix servers to do so.

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Author details

Lukáš Macura[1]*, Jan Rozhon[2] and Jerry Chun-Wei Lin[3]

*Address all correspondence to: macura@opf.slu.cz

1 School of Business Administration in Karvina, Silesian University in Opava, Karvina, Czech Republic

2 Faculty of Electrical Engineering and Computer Science, VSB—Technical University of Ostrava, Ostrava, Czech Republic

3 School of Computer Science and Technology, Harbin Institute of Technology Shenzhen Graduate School, Shenzhen, Guangdong, China

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Section 2

Economic, Financial and Managerial Aspects of Sino-International Relations

Chapter 8

New Features of Labor Market and Their Impact in China

Yajun Meng

Additional information is available at the end of the chapter

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Abstract

After 30 years of development, China has great transaction of the labor market from a government-controlled market to a market-driven market. Previous researches stated the various characteristics of Chinese labor market. However, with rapid development, the labor market in China has some new and unpredicted changes in recent years. With the comprehensive, rigorous, and consistent data investigated from 2000 to 2015, which come from the National Bureau of Statistic of China (NBSC), this paper does a descriptive research on verification of common features stated in the previous literature, disclosing some new features and changes of current Chinese labor market. These features include the following: (1) the average wage in society keeps increasing with a relative decrease of return to education; (2) the old pattern of labor mobility, from rural area to urban area, is steady; however, the growth rate of urban population keeps decreasing, and the mobility of labor forces showed significant regional inequality; (3) the effectiveness and conduction of labor law and regulation are challenged by labor market segmentation caused by informal employment; and (4) the labor force participation rate (LFPR) in China keeps stable after 2010, with four different definitions. This paper designs a new way of measurement of informal sectors and indicates that the labor force participation rate in China is steady, not declining, after 2010. This analysis not only provides a complete understating of the current Chinese labor market but also indicates the potential impact and problem caused by these new and changing features of Chinese labor market for researcher and policy-maker.

Keywords: labor market, labor force participation rate, labor mobility, wage, informal employment

1. Introduction

As the world's most populated country, China has a great social and economic reform in the past decades. As a remarkable result of its reform, the labor market of China transformed

from a government-controlled market to a market-driven market. From the beginning of Chinese reforming and opening, which started from the agriculture field in 1978 to encourage rural labor to produce for their own interest with the legalization of "private property of land" by long-term contract signed with the government, the controlling of labor liquidity was released. With the rapid development of private and collective-owned enterprises around the whole country, the flexible labor force in China started to move from rural area to urban area and from agriculture to industry.

In the first stage of labor market reform from 1978 to 1992, the liquidity of labor force was a limited scale; the employment of free rural labor force concentrated in the enterprises in township and seasonal employment sector. There was still strictly market segmentation in labor market between rural and urban and the state-owned economic sector and other economic sectors.

From 1993 to 2002, the second stage of the reform of labor market is the creation of marketing structure of labor market began, which caused market-oriented wage reform. The political controlling of labor liquidity was more easy than before, and with the rapid construction of urban area, more and more rural migrants, which were residents of rural but had employment in urban more than 1 year, involved and contributed to these infrastructure construction, manufacturing sectors, and expansion of the city, which contributes about 25% of the economic growth of China [1].

After 2002, with the effect of WTO, the modern Chinese labor market structure has been created, and Hukou system started to reform. The Hukou policy in small-sized and middle-sized city has been released, even abolished for requirement to be a resident in those cities. The barriers reduced, and the flowing of labor from rural area to urban area is stable. The higher educated labor moved from different regions, as well as what the lower quality labor force do. The protection for labor market improved, and several laws and regulations have been issued by the central government, which means more complete legislation of labor market.

The study of Chinese labor market is rich and innumerable. The early studies stated that the main features of Chinese labor market were market segmentation between rural and urban areas and the market distortion caused by Hukou policy and related to institutional regulation [2–4]. Brooks and Tao [5] in IMF stated that the estimated urban unemployment would challenge the growth of Chinese economy with the huge inflow of labor force into big city and suggested to encourage private sectors and more ease of labor mobility.

After 2002, the studies on Chinese labor market were various and focused on different subfields. The characteristics of Chinese labor market stated in these literatures were that the movement of rural migrant workers to urban area kept stable and the keeping of Hukou system management, the emergency of unemployment in Chinese society, the increasing of salary payment but with more inequality, the gap of wage increase which is based on differential of enterprise ownership and industry, and the decline of labor force participation rate gradually and emergency of informal sectors and workers employed in informal sectors had a large proportion in the whole population [6–9]. From 2006, the debate about the aging population in China and the shortage of labor forces are attractive. Cai [1] stated the coming of "Lewis turning point" in China and the lower labor cost finished with negative impact on China's sustainable growth [10].

All these early researches covered different subfields of labor market with their different surveys or data investigated from different resources. The statements of these studies were comprehensive and completely describe the Chinese labor market in the past. However, with the rapid development of Chinese economic and social transforming, they are not satisfied for current analysis and understanding about current labor market. Some of those researches used the statistics data from differential institute or resource; it caused the incongruence of data in their analysis, which weaken the confidence level of their conclusion.

This paper takes a descriptive research on current features of labor market and their impacts in China, all the statistics data are investigated from the National Bureau of Statistic of China (NBSC), and the official data is published by central government to keep the consistency of the analysis and increase the confidence of the result. The analysis takes the newest and long-term data from 2000 to 2015 to verify the common understanding of features of Chinese labor market and disclose some new features and changes in this market. Since the complexity of labor market, the paper only focuses on some subfields of labor market in China, not all the details of this market.

2. Salary payment and return to education

The early study stated the remarkable improvement of payment of Chinese employee and market-oriented wage structure. The new data shown in **Figure 1** proves the trend of increasing the social average salary level, and average salary earned by Chinese is 5169 RMB per month in 2015, which grew fivefold from 2003, which was 1164 RMB per month. At the same time, the first contracted salary of fresh graduates increased with payment differential caused by the education level of employee.

However, the return to education, represented by the ratio of the first contracted salary of graduates to social average salary in same year, has significant declining, as shown in **Figure 2**.

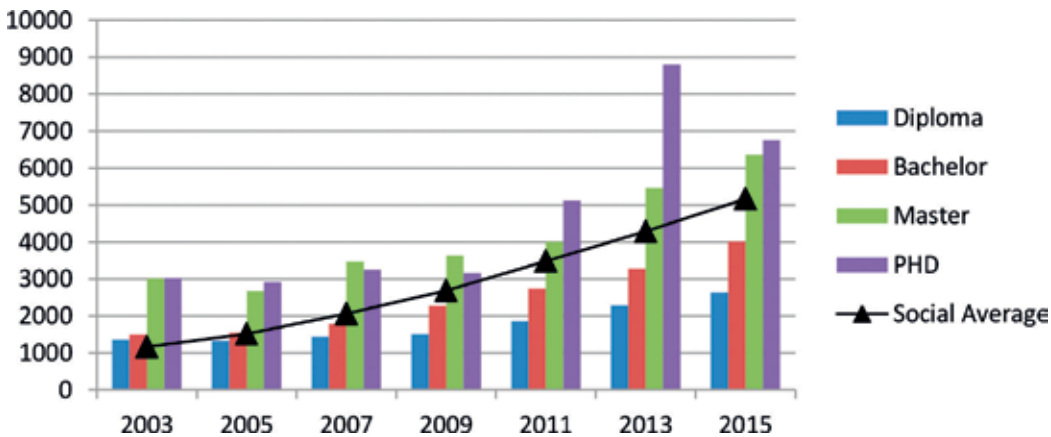

Figure 1. The first salary of different education levels of graduates from 2003 to 2015. Source: Graduates Job Survey 2003, 2005, 2007, 2009, 2011, 2013, 2015, Peking University, National Bureau of Statistic of China.

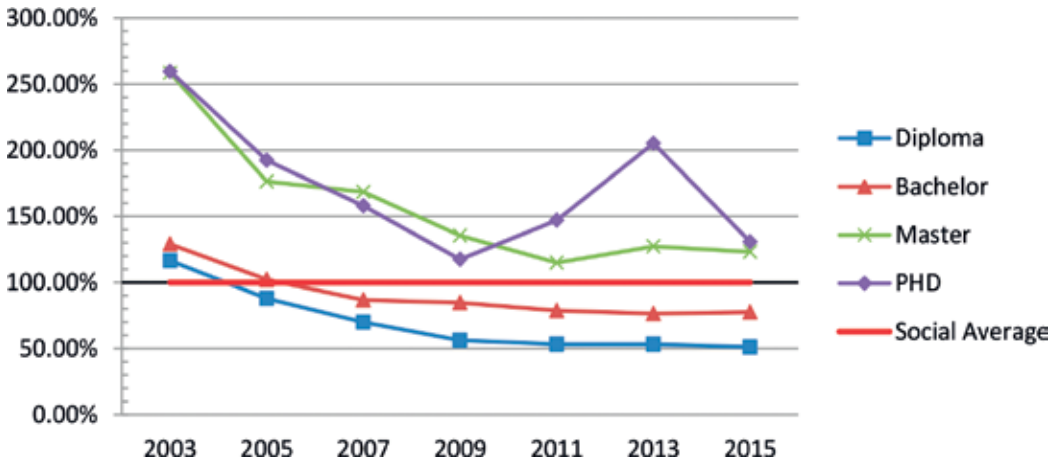

Figure 2. The ratio of the first salary payment for different education levels compared with social-level income from 2003 to 2015. Source: Graduates Job Survey 2003, 2005, 2007, 2009, 2011, 2013, 2015, Peking University, National Bureau of Statistic of China.

The first contracted salary for employee who graduated with diploma and a bachelor's degree was 1356 RMB and 1502 RMB per month, which was much higher than the social average level (1164 RMB per month) in 2003. In 2015, these numbers became 2640 RMB and 4010 RMB per month, which were only 51% and 77% of the social average salary level. Only graduates with the higher education level (with master's or PhD degree) win the social average payment for their first contracted salary. But, the relative payment of the first salary of the higher education level decreased also, from over 250% of the social average salary in 2003 to about 125% of the social average salary in 2015. Although the first contracted payment does not mean the low payment in the future, it is clear that the traditional high education has less competitive advantage for employee.

The only explanation of the less of payment for graduates is rapidly the increasing number of graduates from 2000 to present. **Table 1** shows the number of graduated students with high education degree from 2000 to 2015, which was less 1 million in 2000 and close to 1 million after 15 years in 2015. The expansion of scale of graduates has a negative effect on the first contracted salary, increasing the unemployment of fresh graduates, but the increase of overall labor quality has a long-term positive effect on Chinese sustainable development [13, 14].

Year	2000	2001	2002	2003	2004	2005	2006	2007
Graduates	0.950	1.036	1.337	1.877	2.391	3.068	3.775	4.478
Year	2008	2009	2010	2011	2012	2013	2014	2015
Graduates	5.119	5.311	5.754	6.082	6.247	6.38	6.59	6.80

Source: National Bureau of Statistic of China [11, 12].

Table 1. Number of graduates with high education in China from 2000 to 2015 (million).

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3. Population mobility and regional inequality

Migration of rural labor force to urban area kept a steady trend in the past 15 years, as shown in **Figure 4**. The urban population size caught up the population in rural area in 2010 and keeps increasing; 771 million of the population were urban residents, and 603 million of the population were rural residents in 2015, as shown in **Figure 3**.

But the growth rate of urbanization in China decreased from 2000 to 2015, as shown in **Figure 4**; the growth rate of urban population was 4.7% in 2000 and declined to 2.9% in 2015.

With steady mobility of labor force around the whole nation, the net inflow of population in different provinces (Chinese mainland) showed different trends. The provinces Guangdong, Jiangsu, and Shanghai had the most net population inflow (the growth of population in Guangdong from 2000 to 2010 was 20.6 million, and this number in Jiangsu was 9.97 million and 8.6 million in Shanghai). However, the provinces Anhui, Sichuan, and Hunan all had net outflow of population from 2000 to 2010 (population decreased as 8.9 million in Anhui, the decrease of population in Sichuan is 7.7 million, and the decrease of population was 6.5 million in Hunan) according to the Fifth and Sixth National Population Census, as shown in **Figure 5**.

Population mobility in China showed evidently regional inequality. Some province attracted more labor force. The labor mobility between the different regions shows simultaneous changes and movement in the past 15 years. **Figure 6** describes rate of population changes in some Chinese provinces from 2000 to 2015. The coherence of different regional population mobilities is strong as shown by a graph with a suddenly shift in 2010.

There is no research or empirical study found for the reasons which caused the shift down in 2010 of rate of population mobility nationwide in early literatures. This paper takes a simple analysis to discover the potential, relative reasons by using GDP data. After several tentatives, it is be found that the trend of GDP with 2-year lagging matches the trend of population mobility mostly, as shown in **Figure 7**. This indicates a new basic evidence for the determining mechanism of movement of Chinese labor force.

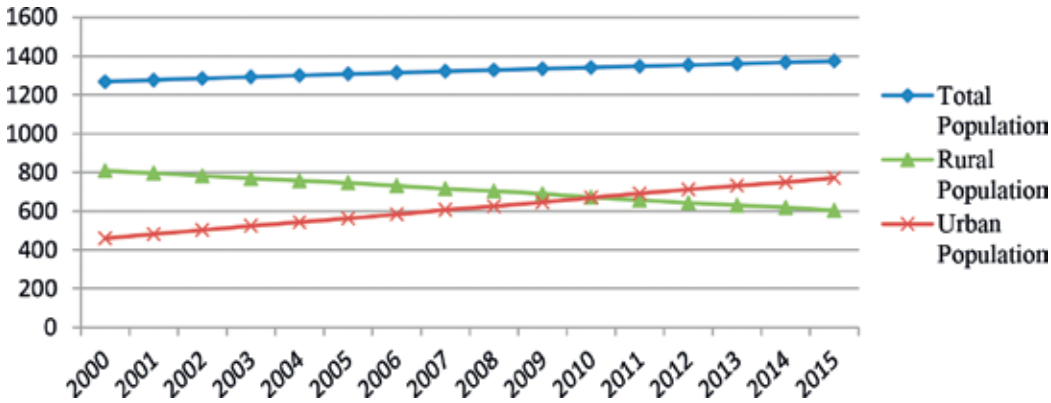

Figure 3. Total rural and urban population in China (2000–2015, million). Source: National Bureau of Statistic of China [11, 12].

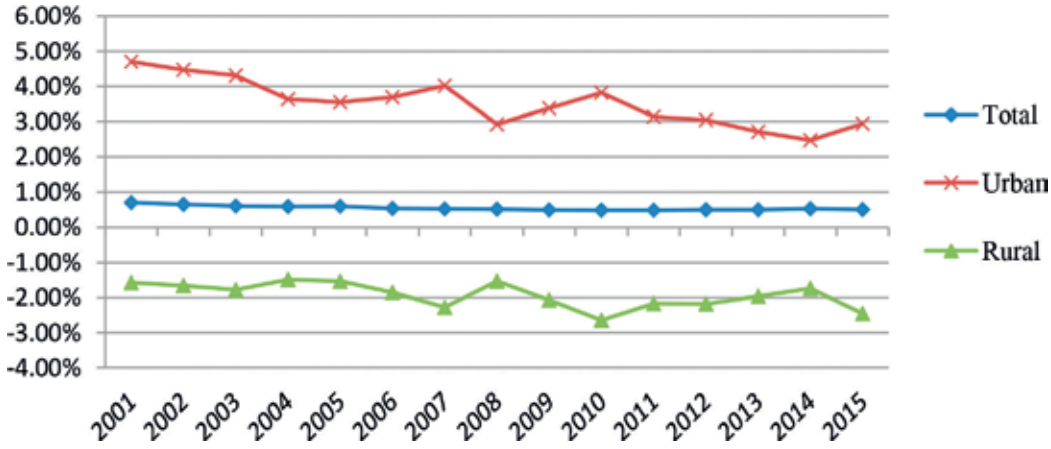

Figure 4. Growth rate of total rural population and urban population in China from 2000 to 2015. Source: National Bureau of Statistic of China [11, 12].

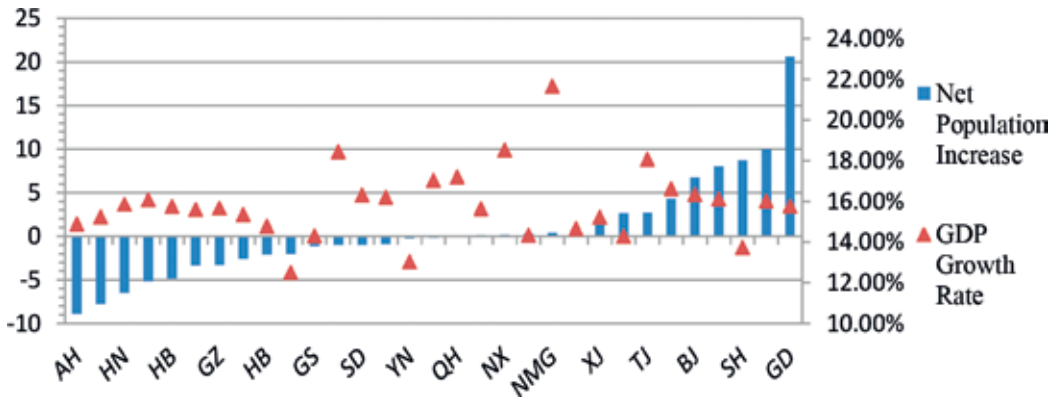

Figure 5. Net increasing of population of different provinces in China (mainland) from 2000 to 2010. Source: The Sixth National Population Census (NBSC).

The mobility of labor force in the past 15 years showed the constant concentration toward to super-large city or the metropolitan region. To measure the changes of this trend, this paper takes a new way to measure the final location of migrants, which investigates the number of cities with different population sizes. The changes of the number of cities with different sizes indicate the final location of migrants and mobility of labor force. The number of big and super-large cities (have more than 1 million of the population) keeps rapidly increasing from 2000 to 2015, and the number of middle and small cities (with population between 0.2 and 1 million) becomes less as meanwhile, as shown in **Figure 8**. The number of cities has more than 4 million of the population increased from 8 to 15 from 2000 to 2015. The number of cities has more than 2–4 million of the population increase from 12 to 28, and the increasing rate was 216% from 2010 to 2015. The number of cities with population size between 0.5 and 1 million fell from 103 to 92 from 2000 to 2015, and the number of cities with population between 0.2 and 0.5 million declined from 66 in 2000 to 49 in 2015.

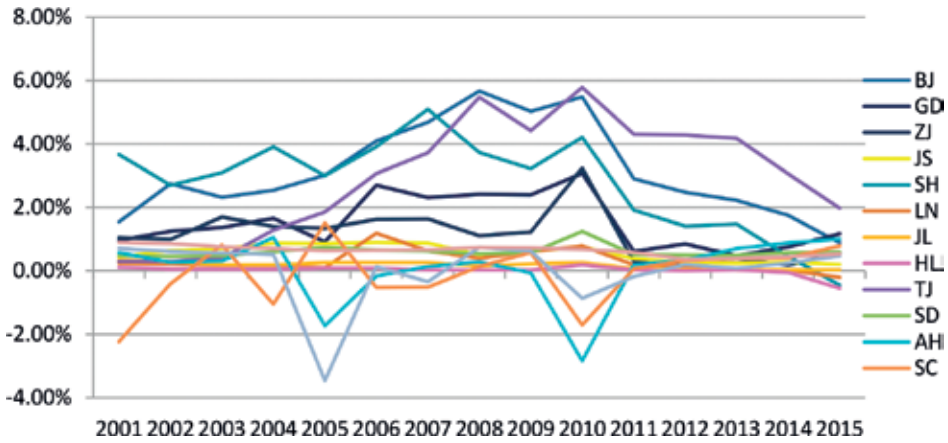

Figure 6. Rate of population changes in some province of China from 2000 to 2015. Source: National Bureau of Statistic of China [11, 12].

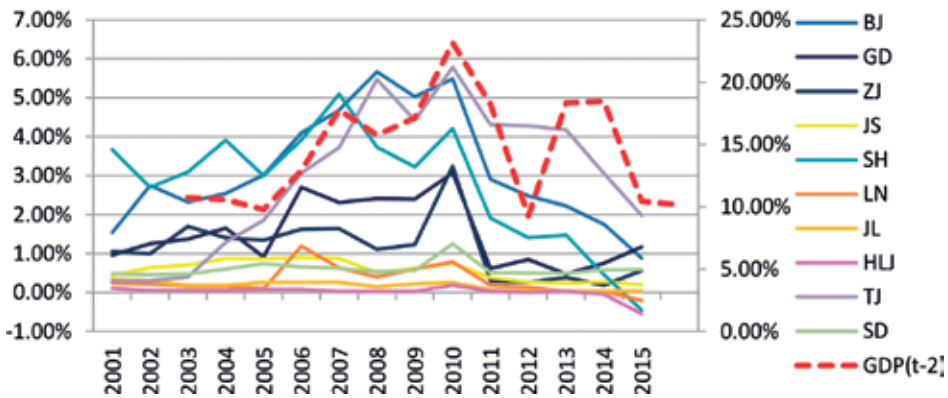

Figure 7. Rate of population changes in some province and GDP growth rate of China (2 years delay), from 2000 to 2015. Source: National Bureau of Statistic of China [11, 12].

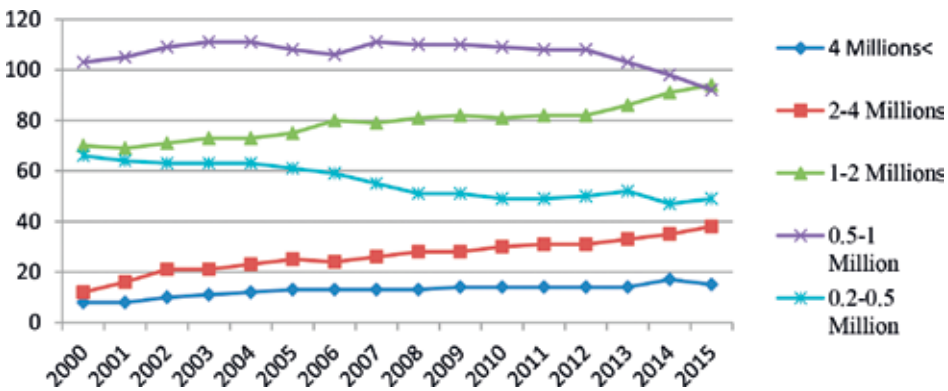

Figure 8. Number of cities with different population sizes in China from 2000 to 2015. Source: National Bureau of Statistic of China [11, 12].

4. Employment in informal sectors

The emergency of informal sectors is the main feature of Chinese labor market as previous research stated. The increase of informal employment creates a significant challenge to take effective labor market policy in the nation for the central government of China. The definition of informal sector or informal employment in China varies in the early study, which includes the indicator of social security coverage, measurement of the self-employment, and non-registered employment [15].

This paper designs a new way of measurement of informal sectors. The formal and informal employments are differently identified in four scenarios based on their employed enterprise's property of ownership sectors. The National Bureau of Statistic of China has full and clear identification of these types of enterprises and data of labor employed in these enterprises. Since the different ownership sector of employer has different effectiveness of conducting labor law or other regulations, it states the different labor protections to the employee.

In the first scenario, formal employment is employment in state-owned company (including government staffs), incorporate company, and FI company, which provide the best protection of labor law in Chinese labor market, and all other employments are informal employment. In the second scenario, the formal employment includes the formal employment in the first scenario and employment in collective and limited liability company. The overall labor protection of employment in collective and limited liability company is not as good as the formal employment in the first scenario but still much better than the other employment in China. All other employments that do not have to be included in these enterprises are informal employments.

As shown in **Figure 9**, it is clear that only 14% of the total labor forces have full protection of labor law which is strictly conducted by state-owned company (including staff in government), incorporate company, and FI company in 2015 with the first scenario. And, this ratio

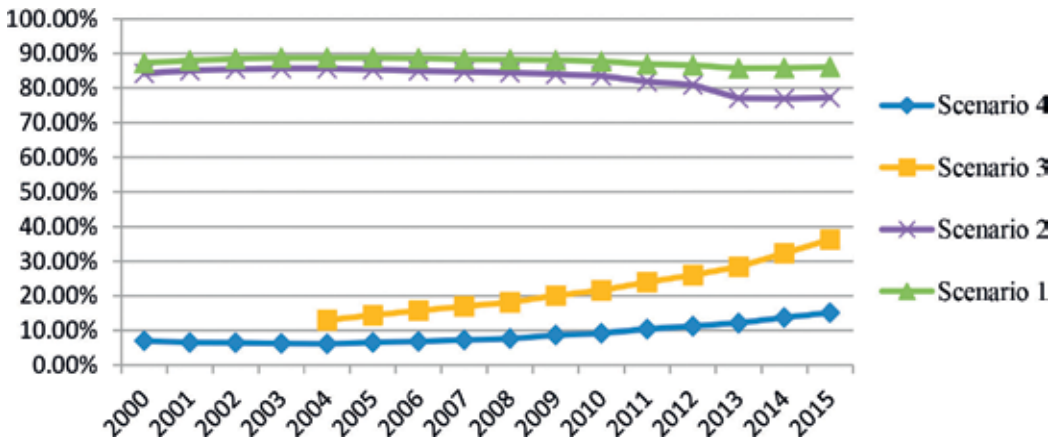

Figure 9. Ratio of informal employment (% of the total labor force) with four different scenarios in China from 2000 to 2015. Source: National Bureau of Statistic of China [11, 12].

keeps stable from 2000. The informal employment was 86% of all labor forces in 2015, as shown in **Figure 9**. The employment rate in formal economic sectors increased to 23% in 2015 with the second scenario which includes the employment in collective and limited liability company. The rate of informal employment was 77% of all labor forces.

In the third scenario, the informal employment is defined as the employment in the private business (exclusive farmer) and the self-employed or individual business (exclusive farmer), which lacks the protection of labor law since the small and unstable property of private business. The ratio of employment in private business, which includes self-employment or individual business, increased rapidly from 12.93% to 36.25% of the total labor forces since 2004, which means that the employee in the informal sectors has grown quickly.

In the fourth scenario, the informal employment is only defined as the employment in self-employed or individual business (exclusive farmer), which has the worst protection of labor law and relative regulation. The proportion of informal employment in this scenario has slowly increased from 7% in 2000 to 15% in 2015, as shown in **Figure 9**.

5. Labor force participation rate

Early studies showed that the labor force participation rate (LFPT) declined since the beginning of the new century. Guo (2011) indicated that the LFPT in China declined from 79.1% in 1990 to 73.4% in 2009, and other researches showed the Chinese LFPT was 77% in 2010 and only 70% in 2015 [16]. The NBSC stated the LFPT of China in 83.0% in 2000 and 80.4% in 2010 with the result from the World Bank. Some domestic studies also stated the different calculations of this important indicating index based on their survey.

The previous differential of LFPT causes the confused understanding and wrong statement of labor market, even with wrong decision-making. The reason of these problems is caused by different definitions of LFPT and method of calculation. In the paper, four different definitions of LFPT are stated as the following:

Method or definition (1) is the definition introduced by the International Labour Organization (ILO).

$$\text{LFPT} = \text{Labor force divided by the total working age population (15+)} \quad (1)$$

Method or definition (2) which is designed by this paper is the stricter definition based on method (1).

$$\text{LFPT} = \text{Labor force divided by sum of the total working age population (15+) minus student enrolled in high school and university} \quad (2)$$

Method or definition (3) is the definition introduced by the OECD [17].

$$\text{LFPT} = \text{Labor force divided by the total working age population (15–64)} \quad (3)$$

Method or definition (4) is the definition introduced by X.Q. Zeng [18].

$$\text{LFPT} = \text{Labor force divided by the total population} \quad (4)$$

Figure 10 shows the different calculation of LFPT in China with four definitions from 2000 to 2015 and the LFPT stated by ILO.

These results show that with the data used by ILO and data investigated from NBSC in this paper, with the definition introduced by ILO, the LFPT lines match well, which declined from 77% in 2000 to 70% in 2010. This proved the conclusion in early study that LFPT showed decrease before 2010 with definition introduced by ILO. However, with the newest data investigated in this paper, it is clear that the LFPT kept stable, not declining as before after 2010. The LFPT in China is 70.09% in 2010, 69.80% in 2011, 69.75% in 2012, 69.72% in 2013, 69.77% in 2014, and 69.80% in 2015. This result is significantly different with the conclusion stated before.

In China, the student enrolled in high school and university is not available for labor market. Therefore, the LFPT calculated with method (2) is more reasonable to express the willingness to be employed by labor force in China. LFPT calculation excluding students was 77.1% in 2010, which declined to 73.14 in 2010 and kept stable after 2010 with 72.98 in 2015, which is 3% higher than the result in method (1).

With the definition introduced by OECD [17], the LFPT declined from 84.9% in 2000 to 82.3% in 2010 and then increased slightly after 2010; it was 83.4% in 2014 and 84% in 2015. This discovery conflicted with the early study, with a significant difference. And, the result based on OECD [17] method shows that more labor forces in the main group (15–64) of labor supply in the market are willing to be employed after 2010, not less as before.

The calculation of LFPT based on method (4) shows stable trend from 2000 to 2015; the LFPT of China was about 58% in the past 15 years.

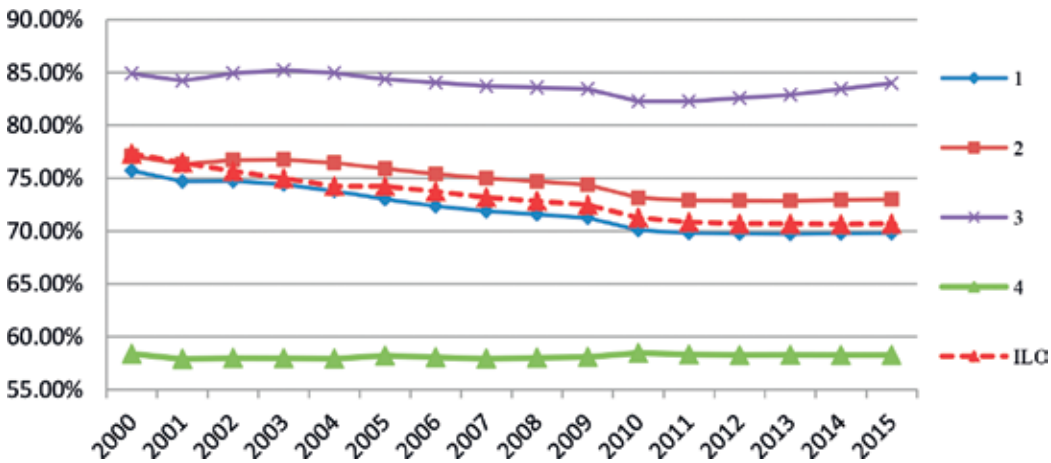

Figure 10. LFPT with four kinds of definition in China. Source: National Bureau of Statistic of China [11, 12] (WB).

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6. Conclusion

This paper focuses on the current features of Chinese labor market in recent years with a descriptive research and discloses some changing characteristics of Chinese labor market, which are different and even conflicted with the result of what the previous research did. The data used in this paper were investigated by the National Bureau of Statistic of China, which have more confidence level and consistency.

The first observation of this paper is the stable increase of average salary in the society. But, the relative return to education with all education level, represented by the first contracted salary after graduation from university in this paper, declined. It is clear that the expansion of Chinese high education has a negative effect to this lower return to education. With the market-oriented salary structure in labor market of China, this observation indicates the mismatch of supply of skilled labor and its demand. The government should invest more for skilled worker training in special institutes and balance the skilled force supply, with some official indicator that can represent the labor market demand of China.

On the other hand, the education is important for the individual and society, as key component of the human capital. The expansion of the size of high-quality labor force is helpful for Chinese development in the future. The higher education level of Chinese labor force also helps the challenge of aging population. The economic development in China needs to be driven by more quality factor not only by the quantity factor of labor force.

The second observation in this paper is the stable mobility of rural labor force to urban area with declining velocity. The inequality of regional population movement is significant in this paper. The provinces along seacoast have much more population growth compared with the population decline in other provinces in inland of China. However, the trend of labor force mobility had a shift in 2010, the speed of mobility showed down. Using the GDP of China with 2-year lagging, the trend of GDP matched the trend of changes of mobility in Chinese labor market very well. One potential explanation of this shift of movement of labor force in 2010 is the effect of the global financial crisis in 2008, with a 2-year delay to labor market in China.

With a new method of measuring the final location of migrants in this paper, which used the number of cities with different population sizes, it is clear that more and more migrants concentrated in large city or metropolis. The migrants from rural area show directly inflow to large cities with skipping of small and middle cities.

The outburst of migrants causes a great challenge of environmental protection, society safety, public services, and social insurance to those large cities. The reform of Hukou policy in small and middle cities did not get the expected result, which is designed to attract migrants to stay with the easy or abolishing Hukou requirement of resident. On the other hand, the strength of controlling the population size in large city or metropolis, with the pressure of large population, required more strict conduction of Hukou policy in those areas. The government should take more policy and work to encourage employment in private sectors and self-employed to avoid unemployment in large city and to encourage the rural labor forces to stay in small and middle city.

The third observation of this paper is the large proportion of informal employment in China in four different scenarios. This challenges the conduction and effectiveness of labor law and regulation in China; more informal employment means less protection of labor force in the market. In the third scenario, it is clear that 36% of the total labor forces, which is employment in private business or self-employment, are lack of the protection of labor law or regulation, since the level of protection is determined by the size of enterprise and property of ownership. These employments keep increasing based on this analysis, as shown in **Figure 9**. And, this increasing informal employment will cause more challenge for conduction and effectiveness of labor law and relative regulation. The government needs to have more flexible labor market policy and social safety policy covering the employment in informal sectors. The assistance agency in labor market should be encouraged to help labor force for law protection and also support the conduction of effectiveness of labor market regulation and law.

The fourth observation in this paper is the stable and high labor force participation rate in China after 2010. The calculations of *LFPR* with different definitions all show the same trend in Chinese labor after 2010. This is a new disclosure in this paper. This indicator shifted from declining trend before 2009, as stated in the previous research, to stable trend after 2010 with the ILO definition. More than that, it is clear that the *LFPR* kept almost stable since 2000 to 2010 and had increased after 2010 if using the definition introduced by the OECD [17], which is more reasonable to measure the willingness of employment in China. This result should be considered for the current and future policy-making and market evaluation of labor market in China.

Author details

Yajun Meng[1,2]*

*Address all correspondence to: yajun.meng@vsb.cz

1 Faculty of Economics, Technical University of Ostrava (VSB-TU), Czech Republic

2 Hebei GEO University, China

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Chapter 9

Review of Applying European Option Pricing Models

Haochen Guo

Additional information is available at the end of the chapter

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Abstract

An option is a derivative financial instrument that establishes a contract between two parities concerning the buying or selling of an asset at a reference price. The price of an option derives from the difference between the reference price and the value of the underlying asset plus a premium based on the time remaining until the option. The paper illustrated in both the binomial and the Black-Scholes models, which value options by creating replicating portfolios composed of the underlying asset and riskless leading or borrowing.

Keywords: European options, the binomial option pricing model, the Black-Scholes model, JEL classification: G1, G12, G15, C5

1. Introduction

The goals of the paper present review of option pricing models illustrated in both the binomial and the Black-Scholes models. In the paper, it generally divides option pricing part and part of binomial model and the Black-Scholes model. The first section presents option pricing theory and models. The second section describes the binomial option pricing model. The third section is about the Black-Scholes model. The last section is the conclusion.

2. Option pricing theory

An option provides the holder with the right to buy or sell a specified quantity of an underlying asset at the exercise price on or before the expiration date of the option. Since it is a right and not an obligation, the holder can choose not to exercise the right and allow the option to

expire. According to that summarizes the options, variables increasing with the effect of call/put option prices:

- Underlying asset's price: increase of call price and decrease of put price.
- Exercise pricing: decrease of call price and increase of put price.
- Variance of underlying asset: both increases of call and put prices.
- Time to expiration: both increases of call and put prices.
- Interest rates: increase of call price and decrease of put price.
- Dividends paid: decrease of call price and increase of put price.

Option pricing theory has made vast strides since 1972, when Black and Scholes published paper "the pricing of options and corporate liabilities" in the Journal of Political Economy. Black and Scholes used a "replicating portfolio": a portfolio constituted the underlying asset and the risk-free asset, and they had the same cash flows as the option being valued of final formulation. However, the mathematical derivation is complicated, although binomial model is simpler for options valuation with same logic.

3. The binomial option pricing model

The binomial option pricing model depends on a simple formulation for the asset price process in any time period can move to one of two possible prices. Suppose an investor focuses estimates on how stock prices change between sub periods, rather than on the dollar levels. That is, beginning with stock price, for the next sub period forecasts:

- first is 1+% change for an up movement(μ);
- second is 1+% change for a down movement(d).

Additional, to the point of accumulation, the number of requisite forecasts. Assume that the same values for up movement and down movement apply to price change in all subsequent sub period. Under these assumptions, the investor need only forecast up movement, down movement, and N-the total number of sub periods.

The binomial option pricing model consists of the forecasted stock price and option value trees. The upper panel presents after μ and d during the first two sub periods, the initial stock price of S will have changed to $(\mu d)S = (d\mu)S$, and it means the forecast does not depend on whether the stock price begins its journey by increasing or decreasing. As before, once μ,d, and N are determined, the expiration date payoffs to the option (i.e.,$c_{\mu\mu\mu}$, $c_{\mu\mu d}$, $c_{\mu dd}$, *and* c_{ddd}) are established.

Hence, the formula for an option in sub period t can be inserted into the right-hand side of the formula for sub period t−1. Carrying this logic all the way back to date 0, the binomial option valuation model becomes

$$c_0 = \left\{ \sum_{j=0}^{N} \frac{N!}{(N-j)!j!} p^j (1-p)^{N-j} \, max\left[0, (\mu^j d^{N-j})S - X\right] \right\} \div r^N, \quad (1)$$

where $N! = [(N)(N-1)(N-2)\ldots(2)(1)]$ to interpret (1), the ratio $[N! \div (N-j)!\, j!]$ states how many distinct paths lead to a particular terminal outcome, $p^j(1-p)^{N-j}$ states the outcome probability, and max$[0, (\mu^j d^{N-j})S - X]$ states the payoff. Assume m be the smallest integer number of up movement, the option will be in the money at expiration (i.e., $(\mu^m d^{N-m})S > X$), this formula can be reduced by the following Eq. (2).

$$c_0 = \left\{ \sum_{j=m}^{N} \frac{N!}{(N-j)!j!} p^j (1-p)^{N-j} \left[(\mu^j d^{N-j})S - X\right] \right\} \div r^N. \quad (2)$$

3.1. Illustration 1 valuing an option using the binomial model

SPDR S&P 500 ETF Trust (SPY) is an exchange-traded fund. The trust corresponds to the price and yield performance of the S&P 500 Index. The S&P 500 Index is composed of 500 selected stocks and spans over 24 separate industry groups. The Fund's investment sectors include information technology, financials, energy, health care, consumer staples, industrials, consumer discretionary, materials, utilities, and telecommunication services.

Suppose that the riskless rate r is 10% p.a., the time to maturity T is 0.5 year, the initial price of the underlying asset is 134.76 m.u., the volatility σ = 18.06% p.a., the exercise price X is 70.26 m.u. It is also supposed that the time interval T is split into n = 1000 subintervals of equal length.

Task is to determine the price of the European call option on the basis of the multi period binomial model. Illustrate the probability distribution for both, the underlying asset price and the intrinsic value at maturity T graphically.

Following **Table 1** presents input data of determined parameters.

First step (**Table 2**) to calculate the probabilities for a state j (using the sample of number 30)π_j and stock price for $S_{T,j}$, intrinsic value of the option for $IV_{T,j}$, and product of π_j, $IV_{T,j}$.

Finally, the option price calculated by discounting the mean value of the intrinsic value, the result of option price is 68 m.u. Following **Figure 1** shows illustration depicts that the probability distribution for both, the stock price and the intrinsic value of the option at maturity time.

Risk-less rate, r	Number of steps, n	Time to maturity, T	Initial underlying asset price, S0	Exercise price, X	Volatility, σ	Up-ratio, μ	Down-ratio, d	Probability, p	Discount factor, df
10%	1000	0.5	134.76	70.26	18.06%	1.004046504	0.995969804	0.505181219	0.951230613

Table 1. Determined parameters.

Up movements	Probability	Stock price	Intrinsic value	Productπj, $IV_{T,j}$
0	0.0000	66.9559	0.0000	0.0000
1	0.0000	70.1521	0.0000	0.0000
2	0.0000	73.5008	3.2408	0.0000
3	0.0000	77.0093	6.7493	0.0000
4	0.0000	80.6854	10.4254	0.0001
5	0.0000	84.5369	14.2769	0.0005
6	0.0002	88.5723	18.3123	0.0033
7	0.0007	92.8003	22.5403	0.0155
8	0.0022	97.2301	26.9701	0.0602
9	0.0061	101.8714	31.6114	0.1944
10	0.0146	106.7342	36.4742	0.5310
11	0.0298	111.8292	41.5692	1.2405
12	0.0533	117.1674	46.9074	2.4986
13	0.0832	122.7603	52.5003	4.3654
14	0.1138	128.6203	58.3603	6.6432
15	0.1369	134.7600	64.5000	8.8292
16	0.1447	141.1928	70.9328	10.2625
17	0.1343	147.9326	77.6726	10.4334
18	0.1094	154.9942	84.7342	9.2674
19	0.0779	162.3928	92.1328	7.1749
20	0.0483	170.1447	99.8847	4.8232
21	0.0259	178.2665	108.0065	2.7999
22	0.0120	186.7761	116.5161	1.3931
23	0.0047	195.6918	125.4318	0.5881
24	0.0015	205.0332	134.7732	0.2078
25	0.0004	214.8205	144.5605	0.0603
26	0.0001	225.0749	154.8149	0.0140
27	0.0000	235.8189	165.5589	0.0025
28	0.0000	247.0757	176.8157	0.0003
29	0.0000	258.8699	188.6099	0.0000
30	0.0000	271.2270	200.9670	0.0000
sum	1.00			71.4093

Table 2. Calculation of probabilities, stock price, intrinsic value, and product.

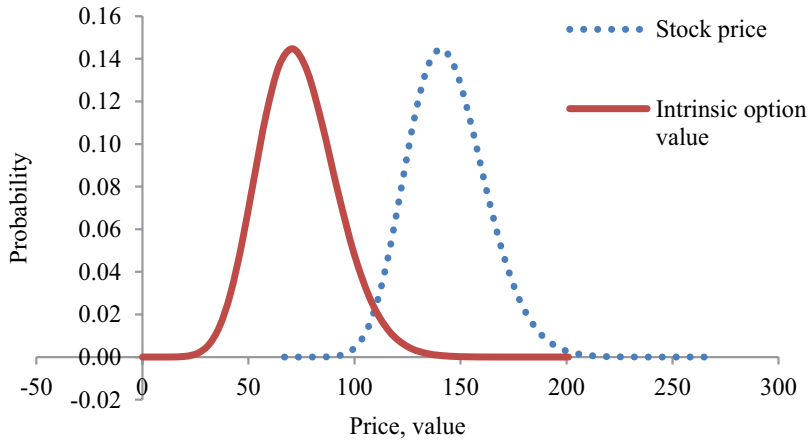

Figure 1. Probability distribution.

4. The Black-Scholes model

The Black-Scholes model assumes that a statistical process known as geometric Brownian motion can describe stock price movements. This statistical process summarized by a volatility factor σ, which is analogous to the investor's stock price forecasts in the previous models. Formally, assumed the Black and Scholes' stock price process is

$$\frac{\Delta S}{S} = \mu[\Delta T] + \sigma \in [\Delta T]^{1/2}. \tag{3}$$

Hence, the equation presents stock's return ($\Delta S/S$) that relates to expected component ($\mu[\Delta T]$) and a "noise" component ($\sigma \in [\Delta T]^{1/2}$) in any future period T. μ is the mean return and $\in$ states the standard normally distributed random error.

Assuming Black and Scholes used the riskless hedge to get the following formula for no dividend-paying stock call option valuation:

$$c_0 = \mathrm{SN}(d_1) - X(e^{-(\mathrm{RFR})T})N(d_2), \tag{4}$$

where $e^{-(RFR)T}$ is the continuously compounded variables discount function.

The variable $N(d)$ represents the cumulative probability, the value from the standard normal distribution $\leq d$. As the standard normal distribution is symmetric around zero, a value of d = 0 would lead to N(d) = 0.5000:

- positive values of d would then have cumulative probabilities > 50%,
- negative values of d leading to cumulative probabilities < 50%.

The option's value is a function of five variables, there are current security price (S), exercise price (X), time to expiration (T), risk-free rate (RFR), and security price volatility (σ). Hence, the Black-Scholes model holds that $c = f(S, X, T, RFR, \sigma)$. S and RFR are observable market prices, and X and T are defined by the contract itself. Thus, the only variable an investor must provide is the volatility factor.

4.1. Illustration 2 valuing an option using the Black-Scholes model

Suppose that known all parameters that are needed to apply the Black-Scholes model, r, S0, dt, X, and σ. All input data are shown in **Table 3**.

Task is to determine the price of the European call option on the Black-Scholes model.

First step to calculate the prices of options. Following **Table 4** presents the procedure of prices of options.

Following **Table 5** and **Figure 2** describe the result of options prices.

Options	Riskless rate	S0	dt	σ	X
Option 1	0.1	134.76	0.5	18.060%	70.26
Option 2	0.1	134.76	0.5	21.060%	80.26
Option 3	0.1	134.76	0.5	24.060%	90.26
Option 4	0.1	134.76	0.5	27.060%	100.26
Option 5	0.1	134.76	0.5	30.060%	110.26
Option 6	0.1	134.76	0.5	33.060%	120.26
Option 7	0.1	134.76	0.5	36.060%	130.26
Option 8	0.1	134.76	0.5	39.060%	140.26
Option 9	0.1	134.76	0.5	42.060%	150.26
Option 10	0.1	134.76	0.5	45.060%	160.26
Option 11	0.1	134.76	0.5	48.060%	170.26
Option 12	0.1	134.76	0.5	51.060%	180.26
Option 13	0.1	134.76	0.5	54.060%	190.26
Option 14	0.1	134.76	0.5	57.060%	200.26
Option 15	0.1	134.76	0.5	60.060%	210.26
Option 16	0.1	134.76	0.5	63.060%	220.26
Option 17	0.1	134.76	0.5	66.060%	230.26
Option 18	0.1	134.76	0.5	69.060%	240.26
Option 19	0.1	134.76	0.5	72.060%	250.26
Option 20	0.1	134.76	0.5	75.060%	260.26

Table 3. Input data.

d1	d2	N(d1)	N(−d1)	N(d2)	N(−d2)
2.7777	2.6500	0.9973	0.0027	0.9960	0.0040
1.9451	1.7962	0.9741	0.0259	0.9638	0.0362
1.3674	1.1973	0.9143	0.0857	0.8844	0.1156
0.9513	0.7599	0.8293	0.1707	0.7763	0.2237
0.6428	0.4302	0.7398	0.2602	0.6665	0.3335
0.4089	0.1751	0.6587	0.3413	0.5695	0.4305
0.2284	−0.0266	0.5903	0.4097	0.4894	0.5106
0.0871	−0.1890	0.5347	0.4653	0.4250	0.5750
−0.0246	−0.3220	0.4902	0.5098	0.3737	0.6263
−0.1138	−0.4325	0.4547	0.5453	0.3327	0.6673
−0.1855	−0.5253	0.4264	0.5736	0.2997	0.7003
−0.2434	−0.6044	0.4039	0.5961	0.2728	0.7272
−0.2902	−0.6724	0.3858	0.6142	0.2507	0.7493
−0.3281	−0.7315	0.3714	0.6286	0.2322	0.7678
−0.3587	−0.7834	0.3599	0.6401	0.2167	0.7833
−0.3834	−0.8293	0.3507	0.6493	0.2035	0.7965
−0.4031	−0.8702	0.3434	0.6566	0.1921	0.8079
−0.4188	−0.9071	0.3377	0.6623	0.1822	0.8178
−0.4310	−0.9405	0.3332	0.6668	0.1735	0.8265
−0.4403	−0.9710	0.3299	0.6701	0.1658	0.8342

Table 4. Procedure of prices of options (a).

4.2. Summary: the binomial model vs. the Black-Scholes model

The number of steps affects the option price and the price determined by the binomial model converges to the analytical solution of the Black-Scholes model. Then we will get the options prices to compare with Black-Scholes model and binomial model in different number of steps. It is easy to see that the result of binomial model is around by the continuous time of Black-Scholes model. Following **Figure 3** presents verification of options prices between two models, the results of number of steps will be select by sample.

When the process is continuous, the binomial model for pricing options coverages on the Black-Scholes model. The advantage of the Black-Scholes approach:

- riskless hedge method leads to a relatively simple,
- closed-form equation capable of valuing options accurately under extensive situation.

Options	Call option
Option 1	67.8267
Option 2	57.6927
Option 3	47.2716
Option 4	37.7111
Option 5	29.7951
Option 6	23.6162
Option 7	18.9135
Option 8	15.3523
Option 9	12.6407
Option 10	10.5544
Option 11	8.9299
Option 12	7.6504
Option 13	6.6325
Option 14	5.8168
Option 15	5.1603
Option 16	4.6318
Option 17	4.2081
Option 18	3.8721
Option 19	3.6109
Option 20	3.4145

Table 5. Options prices.

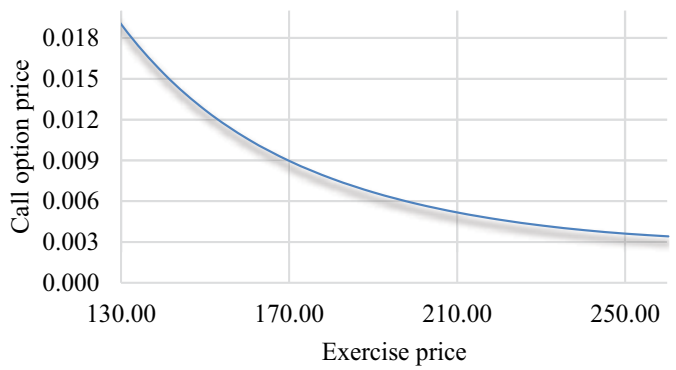

Figure 2. Dependency of a call option price on an exercise price.

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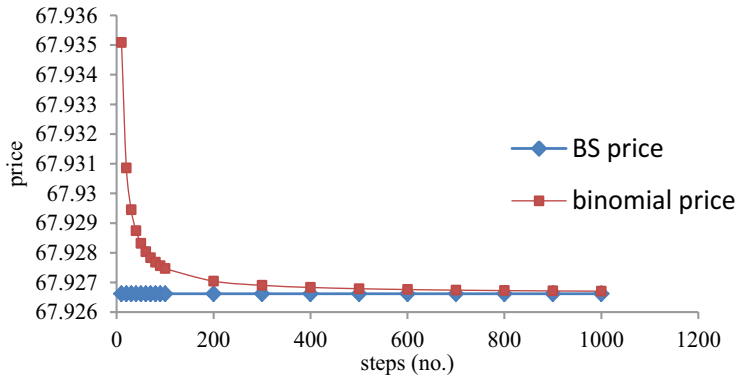

Figure 3. Verification of applying prices of European options using binomial model and Black-Scholes model.

5. Conclusion

This paper presents two classic option pricing model and illustrated the binomial model and the Black-Scholes model based on the same theoretical foundations and assumptions (such as the geometric Brownian motion theory of stock price behavior and risk-neutral valuation). The Black-Scholes option pricing model is the first successful option pricing model, published in 1973, and is based on stochastic calculus. It focuses on the pricing of European options, in which the underlying does not pay a dividend in the option period. The option is priced according to the value of the underlying, the volatility of the value of the underlying, the exercise price, the time to maturity, and the risk-free rate of interest. The model provided a general approach to option pricing and has given rise to a number of other option pricing models. The same underlying assumptions regarding stock prices underpin both the binomial and Black-Scholes models: that stock prices follow a stochastic process described by geometric Brownian motion. As a result, for European options, the binomial model converges on the Black-Scholes formula as the number of binomial calculation steps increases. In fact, the Black-Scholes model for European options is really a special case of the binomial model where the number of binomial steps is infinite.

Author details

Haochen Guo

Address all correspondence to: haochen.guo@vsb.cz

Department of Finance, Faculty of Economics, VŠB—Technical University of Ostrava, Ostrava, Czech Republic

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Chapter 10

The Way of Building Human Capital in China

Małgorzata Wróblewska and Maria Bernat

Additional information is available at the end of the chapter

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Abstract

The current global economic expansion aims to strengthen China's economy and its economic and political system both domestically and internationally. The recommendations of the PRC authorities are unequivocally expressed in propaganda slogans published in the media. The slogans suggest that people seek to compete with each other in business and science, to create thriving businesses, and to develop their own careers. To this end, people should be educated. The educated human capital is to provide the PRC with a high competitive advantage in the high-technology industry and support the development of the innovative knowledge-based service field. In order to achieve this, a balanced support for the education of young people both in the humanities and in the sciences is required. Therefore, the ideas outlined in the following paper refer to concepts based on human capital and its impact on the innovativeness of the economy. The purpose of this publication is an attempt to identify selected determinants of human capital development, the quality of which influences the innovativeness of the economy of the People's Republic of China. Among the most important are the education and activities undertaken by the PRC authorities. It is, according to the authors, human capital that could develop faster when surrounded by the innovation economy and if a number of reforms were undertaken to improve human capital's quality. In order to verify this thesis, studies of subject literature were conducted, and selected analyses in education and innovation were conducted.

Keywords: China, education, innovation, human capital, business culture, economic development

1. Introduction

For hundreds of years, the Chinese Empire was the most economically and technologically developed region in the world. The Chinese dominated other civilizations in areas such as

water engineering, pottery, communication, navigation, agriculture, crafts, shipbuilding, transportation, military equipment and technology, textile, mining and natural resource processing, and many more [1].

During the nineteenth century, China did not participate in the industrial revolution, which changed the global economy by providing Europe with a competitive advantage over other regions of the world. At that time, the Middle Kingdom was riddled with internal conflicts and shut off from the spread of innovation from abroad. The devastation of the Chinese economy was also caused by their engagement in costly wars, which suppressed China's economic and technological development. Mao Zedong's government and his utopian social and economic programs further plunged China into stagnation. The potential of the largest nation in the world was unlocked by the reforms of Deng Xiaoping in the late 1970s. Since then the PRC has sought to restore its status as the world's largest and most innovative economy [2].

One cannot forget the geographical size of the area and the enormous size of the population living in the Middle Kingdom, which is reflected in the grand scale of all social and economic undertaken activities.

M. Elvin formulated the theory of the "high-level equilibrium trap," which is an interesting explanation of China's delayed development during the period of rapid development within European countries. According to Elvin, the Chinese economy was advanced enough to fully meet the needs of society, especially its elite. The elite of Chinese society included highly qualified human resources, probably reinforced by a competitive exam system. The easy-to-access and cheap labor force reduced motivation for applying solutions which would both help to automate work processes and encourage the design of machines capable of replacing workers. An efficient transport system, which made use of rivers and canals, boosted trade rapidly, making all sorts of goods available even during crop failures and natural disasters. The large market enabled the sale of virtually every manufactured product providing a disincentive for reducing production costs to fight off competition. The size of the country allowed for the acquisition of new farmland without the need to significantly increase its crop yields. Increased crop yield could be achieved through investments in better hydration systems and the purchase of more efficient machinery or improvements in infrastructure. The wealth and intelligence of the elite, the ready availability of human resources, and relatively high levels of development may have hindered China's further development during this era. Unlike China, European countries such as Poland and Germany suffered from the lack of the ample labor force required for production of goods. Lack of an adequate labor force required these countries to search for solutions which would automate work processes. Additionally, strong competitors enforced cost reduction and improvement in product quality. The relatively insufficient amount of arable land stimulated the increase of productivity in agriculture and the lack of a waterway system which would support trade contributed to the emergence of a steam engine and the development of railways [3, p. 53].

Therefore, the ideas outlined in the following text refer to concepts based on human capital and its impact on the inattentiveness of the economy. The aim of this publication is an attempt to identify selected determinants of human capital development, the quality of which influences the inattentiveness of the economy of the People's Republic of China. Among the most

important are the historical factors, education, and the actions of the PRC authorities. It is a research thesis that human capital could develop faster and more strongly in the innovation economy if a number of reforms were undertaken to improve its quality. In order to verify this thesis, literature studies were conducted, and interdisciplinary studies were carried out.

2. Education as a factor in the development of human capital in the PRC

Referring to individual skills and abilities as an element of nation's prosperity dates back to the fifteenth century when W. Petty attempted to measure human capital by means of accumulated remuneration at the national economy level. Over the centuries, the methods of estimating human capital have changed, while the way of defining it today as "knowledge, skills, abilities and other attributes of the individual who are important in economic activity" [4, p. 9] or defined as "the knowledge, skills, abilities and other qualities of the human individual that enable the generation of personal, social and economic welfare" [5, p. 18] does not differ significantly from the definition of A. Smith, who understood human capital as "all useful skills acquired by the inhabitants of a given country" [6, p. 2].

The above definitions make the direct measure of the "resource" of human capital impossible, as human capital can only be estimated through measurable phenomena in statistics and proxy measures and index combinations of these measures.

W. Petty, mentioned above as the precursor of investigating human capital, tried to determine the value of man by age, health, and skills. However, he believed skills are as important as production factors: work, land, and capital. Petty considered human labor as the source of the country's wealth [7, p. 31]. A. Smith also considered skills and qualifications acquired by people as a form of capital. According to Smith the costs of education and training of employees are an investment in their future earning opportunities. Such investment, similarly to the investment in physical capital, should return during the employee's professional life [8, p. 227]. Also other great economists such as D. Ricardo [9] J.B. Say and A. Marshall [10, p. 207], or S. Mill and F. List [11, pp. 11–13] emphasized the importance of human resources, knowledge, and education.

These theories influenced the development of the theory of human capital in the late 1950s and continue until the present day. T. Schultz became the pioneer researcher of individual economic efficiency of education. He limited the measurement of human capital to education due to its investment character. Schultz believed that education raises man's ability to work; therefore, investing in human capital could enable poor people and states to grow and increase their income [12, pp. 18–42]. Further studies were carried out by E.F. Denison, who tried to measure classical factors of production and education for economic growth in the United States between the years 1909–1929 and 1929–1957 [13]. G.S. Becker also made many important findings for the theory of human capital. According to him education can be seen as an investment that brings the learner a certain rate of return considering three components: time, consumption, and investment in education. He has also developed models for analyzing return on investment in various types of workplace training [14]. The influence of growth

of knowledge, skills, and productivity of employees on economic growth was also examined by H. Uzawa. Like E.F. Denison, Uzawa used the modified model of R. Solow, assuming that jobs and capital are the driving forces for economic growth. Labor efficiency can be increased through education, health care, infrastructure, and maintenance. R. Lucas developed Uzawa's model. According to Lucas sustainable economic growth is possible through investment in both physical and human capital. It is also important to invest all savings. The greater the economic growth, the higher the savings, including investment in human and material capital [15, p. 14].

People should increase their savings so that they could invest in physical capital or invest in their own development, e.g., education and professional development. R. Lucas believed that economies with low human and material capital are capable of "catching up" the economies of highly developed countries only by changing their consumption preferences.

This model of Lucas explains to some extent the very rapid development of the Chinese economy since the late 1970s. The Chinese earn low wages but have a very high propensity to save. Therefore, the Chinese banking system accumulated financial resources that could be used to build physical capital and developed education and science [3, p. 17].

Both the works of classics and modern representatives confirm that human capital is important for economic development of countries. The development of economic thought helped in creating models that clearly point to the merits of investing in the development of human potential, both for the benefit of individuals and for countries.

3. Education in the People's Republic of China

According to Gawlikowski, the current economic system in China may be defined as "state capitalism," characterized by extensive state interventionism in the market economy [16, p. 53]. At the same time, the Chinese succeed in maintaining both communism and capitalism without recognizing the apparent contradiction. This phenomenon may be explained in several ways. Firstly, the rise of the People's Republic of China has been perceived by the Chinese primarily as liberation from Western colonialism rather than the creation of a new economic system. Secondly, the attitude of the Middle Kingdom's inhabitants toward the established economic system can be defined as an instrumental approach. The Chinese are searching for the most useful and effective economy.

However, the Chinese do not perceive the nature of the economic system as essential when it comes to determining the nature of the state. That is how the PRC entered the global markets, by accepting economic globalization while at the same time rejecting political globalization. Many Chinese believe that economic integration with Western countries does not require the adjustment of the Western political and social standards.

In China, one can run a business, accumulate wealth, and pursue one's own economic goals, as long as doing so does not jeopardize government policies or the stability of state power. Therefore, competition has a definite framework. Governmental recommendations expressed

explicitly in propaganda slogans presented in the media suggest that people ought to work on personal development for the benefit of the entire of society. Chinese people have to compete with each other in business and science, create thriving businesses, and develop their own careers. To this end, people should be provided with good general upper secondary education in order to create a society in which everyone continues to learn throughout their entire lives. These activities are intended to foster long-term development in all areas of economic and social life, including significantly increasing efficiency, and put the whole of society on a path that will develop their civilization and ensure the growth of their national production, thereby leading to a more prosperous life for all [17, p. 98].

Research conducted in various parts of the PRC indicated that education is crucial for the economic development and innovation of the country. Studies carried out by B. Fleischer, H. Li, and M. Qiang illustrated the strong influence of education on China's development. Their results revealed that Chinese workers who graduated from secondary school are much more productive than those who did not receive such education. The research also demonstrated that higher education contributes to the spread of knowledge and the growth of technology, which significantly supports innovation. In the less developed provinces of China, investment in education may have a more significant impact on economic growth than on infrastructure. Therefore, it is highly recommended for all provinces to invest in human capital as a way to reduce the gaps in the economic development within the PRC [Fleischer B., Li H., Qiang M., 201, p. 229].

In order to change China's competitive position, many reforms of higher education were undertaken so that not only low production costs but also well-educated people and innovative enterprises drive the economy. The reforms aimed at increasing the availability of education for Chinese citizens because by the end of the 1970s, the number of Chinese students aged 18–22 was less than 1%. The results of the changes in education appeared slowly. Between 1984 and 1993, this share ranged between 2 and 3%. By contrast, after 1994, there was a sharp increase in the number of students; in 2003, the proportion of students aged 18–22 was around 20%; and in 2013, their share was up to 29.7% [18].

Between 1991 and 2014, the annual average increase in budget expenditure on education in the PRC reached 17.74% of the country's total budget. The share of budget expenditure in financing education in China over the past 10 years increased from 61.66% in 2004 to 80.53% in 2014 [19].

This budgetary increase illustrates the degree to which the authorities of the Middle Kingdom understand the importance of education to overall national economic development. However, according to the data due to the large number of students, these expenses are insufficient. In 2012, the annual cost per student in China was USD 6.500, while in other countries, the ratio was much higher. For example, in the United States USD 26.400, the United Kingdom USD 13.400, Brazil USD 10.200, or South Korea USD 8.500 [20].

The Chinese authorities have recognized the importance of education for the development of innovation and launched the National Reform of the Education System for the years 2010–2020, which, among others, cover the founding popularization of secondary education and

increasing enrollment in secondary schools to 90% of the population and increasing the number of people attending higher education by 16% or 35 million to make up 40% of the population [21, p. 55].

The implementation of such educational policy provided by the state authorities seems to have noticeable effects of improving human capital. Until recently, large and seemingly huge gaps appeared between China and the most advanced countries in science and independent and significant scientific discoveries. The Middle Kingdom to a great extent had to rely on the innovation and achievements of other countries. The dynamic growth of Chinese companies employing engineers supports the method of developing human capital. Such organizations are getting better and better as compared to their foreign competition both in the internal market and abroad. For example, in 2014, the third most innovative corporation in the world according to Fast's ranking was Chinese Xiaomi. The company, founded on April 6, 2010, produces mainly mobile phones. From 2011 to 2016, Xiaomi's engineers developed 21 models of new high-tech smartphones. Such remarkable success of the company would not have been possible without the support of many specialists educated within the Chinese education system. Why? Because Chinese companies have nearly no ability to recruit workers from abroad: firstly, due to the low wages they offer and secondly because of the law restricting the ability of foreigners to settle and work in China. Therefore, it is legitimate to create adequate human capital in China. In the EU countries, the development of innovative economies is possible when employing a large number of educated professionals within the European Union. International companies have global access to human resources because of attractive remuneration and effective immigration policies of the respective governments (e.g., Germany and BMW) [22, p. 68].

It is generally believed that engineers are crucial to a society's technological development. However, the patent applications from Chinese graduates in engineering, manufacturing, and construction are only ranked fourth in the world in terms of their total number of patent applications. There is no doubt that engineers and builders influence inventions and technological advances, but their training cannot be the country's only strategy for promoting innovation through education. A few years after their graduation, graduates in the fields of the social sciences, economics, and law may also prove to be important for the innovative economy. Unlike graduate engineers, who have the knowledge and ability to take part in research immediately as they enter the profession, graduates in such fields as management, rarely, have the opportunity to directly create or support innovation immediately after graduation. Only when graduates advance to positions where decision-making is strategically important can their significance be noticed. Similarly, graduates in pedagogy must wait a full 8 years beyond their graduation before they can have any real influence on their country's number of patent applications. Only after such time can the results of their work as teachers become noticeable as their students go out into the labor market. The number of patent applications is not correlated with the number of agricultural- and service-related graduates [3,p. 84].

The development of human capital as a way to create a competitive advantage in high-tech industries requires a balance of support for the education of young people in both the humanities and the sciences. It is only then that the development of technological innovation will begin to show have a significant impact on innovative- and knowledge-based services.

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4. Innovation in the People's Republic of China

The innovation of the economy is difficult to measure as it is difficult to define the direct effects of innovations being introduced. For this reason, different methodologies and a variety of measures are used to measure innovation. The most commonly used innovation measure is patent applications and patents.

In 2009, the number of worldwide patents issued in China reached 5%, compared to 50% of patents registered to the United States [17,p. 213]. However, in the years 2009–2011, 74% of the total global increase in the number of patent applications was filed in China. Moreover, the number of patent applications in China increased by 28.48% between 2002 and 2014 [3, s. 162]. In 2011, more than 2 million patent applications were filed among which 526,412 were filed in China, 503,582 were registered in the United States, 342,610 were in Japan, and the distant fourth was South Korea with a much smaller claims. The above data illustrates the changes in the "geographical structure" of innovation. In the second half of the twentieth century apart from the United States, Germany and Japan were the only other countries that took the first place in the number of patents issued worldwide [23, p. 119].

Despite the considerable number of patent applications, Chinese still do not dominate among numerous patents granted. The difference between the number of applications and the number of patents granted to citizens of the PRC is caused by poor quality of many applications.

Another measurement tool for economic innovation is the registration of industrial and utility models. This is increasingly important because often it is not due the usefulness of a given product or the technology used to produce it. Many products are competitive and innovative because of their attractive design. Therefore, more and more companies are reserving these solutions to avoid duplication by competitors. Prior to China's entry into the WTO in 2001, intellectual property rights were poorly protected [Liu and Zhou, 2012, p. 7]. Over time, Chinese authorities increasingly require companies to respect international law. Since 2001 China significantly increased the number of protected designs in China, and in terms of product designation, China is a world leader. For example, in 2014, China registered 701,246 utility models, and Russia 12,557, Germany 10,389, Japan 8947, South Korea 5043, and the United States 2919 [24]. The question remains open whether the claimed usable and industrial designs are indeed innovative and bring significant benefits to the economy. So far, there are few Chinese companies that have the advantage of having a proprietary design in gaining competitive advantage.

It is worth noting that the hierarchy of Chinese companies influenced by both the Confucian philosophy and the belief in the collectivism of all human activities negatively affects innovations. These features of Chinese culture stifle the initiative of employees and discourage the development of individual innovative ideas. However, the Chinese are quite tolerant of the uncertainty inherent in projects related to change and innovation. Such a tolerance has a positive and significant influence on innovation and growth. The long-term orientation of the majority of Chinese people can influence innovation both positively (through the long-term thinking about business development) and negatively (by holding onto financial reserves that might be better used to support R&D) [3, p. 122].

5. Conclusion

China's current global economic expansion aims to strengthen China's economy and Chinese economic and political system in both internal and external markets. The PRC declares that it does not intend to impose anything on outsiders or to interfere in internal affairs but rather to use the global wealth without changing the existing international order [25, pp. 39–40]. Nevertheless, China as a "revolutionary power" has an increasingly strong impact on the global environment in which it operates and, at the same time, the outside world also contributes to the transformation of China.

Acting carefully, China has become the world's largest manufacturer, and Chinese products have been flooding international markets for several years. This process has contributed to the elimination of many jobs in the United States, the European Union, and Japan. Large western corporations as well as medium and small companies have moved and continue to transfer more of their production to China [Kania, 2010, pp. 39–58]. At the same time, these companies use their most up-to-date technologies to increase their competitiveness in the Chinese market. However, most foreign companies have already discovered that their increased emphasis on innovation in China does not improve the attractiveness of their products or services due to the lack of effective protection of intellectual property in the PRC. Organizations that have built their divisions in the PRC and have implemented some new technologies quickly find out that sooner or later the Chinese will copy and use this technology as their own. It is also difficult to compete with the low cost and large scale that underpin the competitive advantage of Chinese entrepreneurs. The Chinese are neither ruthless nor very aggressive. They are conservative and slow but at the same time very hardworking. They learn from mistakes, invest a lot, and constantly think about growth [26, p. 22]. There are two elements to be improved in terms of educational investments for human capital development in China. In 2015, the number of university admissions decreased, and some of the Chinese universities have not fully used their capacity. For many young Chinese, a major obstacle to study is the fees for studying and the costs of staying in university cities. It is necessary to expand the scholarship system for the poor and outstanding students. The easier access to low-interest bank loans and the possibility of repaying them after graduation may also support higher education. Secondly, there is no tradition of employee training organized by employers. The results of the research conducted in nine Chinese provinces and based on a group of ten thousand employees showed that only 45% of employees were trained at the workplace and only 39% received training before starting to work. Therefore, the Chinese government introduced a number of training programs for employees who had moved from rural to urban areas and workers from state-owned enterprises. However, there is no data available as of yet on the effectiveness of this project [3, p. 74].

Switching to a more cost-effective model (limiting credit policies, decreasing export earnings, or increasing labor costs) and focusing on internal needs may require a change in production organization, the production and the education of employees all of which can take up to as many as 10 years [23, p. 14]. The Chinese authorities are fully aware of it.

Author details

Małgorzata Wróblewska and Maria Bernat*

*Address all correspondence to: elenam1@wp.pl

Opole University of Technology, Poland

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