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STATISTICAL ANALYSIS OF REAL TRAFFIC OF MACHINE-TO-MACHINE COMMUNICATION (M2M)

Abstract. The development of digital technology has spawned the concept of the Internet of Things (IoT). The concept basis is the machine-to-machine interaction (M2M) technology, which allows devices to exchange information. The most effective data transmission medium for M2M devices is mobile communications. Rapid growth of machine-to-machine M2M traffic in mobile communication network defines the actuality of the research problem, its features and characteristics. Research outcomes are indispensable at the network modeling, planning, analyzing the M2M traffic impact at quality of service (QoS) of mobile network communication. The article analyzes the real traffic in the LoraWan network. Aggregated traffic coming to the network server from all devices is considered. To model the M2M batch traffic, apart from specifying the statistic characteristics it is necessary to assess its self-similarity. In order to define the traffic self-similarity there has been computed Hurst parameter. On the basis of STATISTICA programs batch we have conducted statistical analysis and short-term forecasting of real M2M traffic by method of exponential smoothing.

Key words: Internet of Things (IoT), M2M traffic, mobile communication network, Hurst parameter, forecasting, statistical analysis.

Introduction. International Telecommunications Union ITU-T Y.2060 recommendations [1] define Internet of Things (IoT), as an information community, maintaining innovative services organizing relations between the things (physical or virtual) on the basis of existing and developing compatible information and communication technologies.

An important role in information and communication technologies, securing the future of Internet of Things, will play the compounds in the form of Machine type Communication or “machine-to-machine” (M2M) compound. The compound type thereof represents the form of data transmission between the devices, which does not require obligatory interaction with a human being [2, 3].

The most efficient data transmission media for M2M devices is mobile communication. M2M services market in the years coming shall become one of the perspective and dynamically developing services market for mobile operators.

Rapid growth of M2M traffic envisages the actuality of its properties and characteristics research in the mobile communication network.

M2M traffic exercises a significant influence at services quality in the mobile communication networks and their operation processes. Traffic peculiarities and its characteristics shall be taken into account upon specifying parameters, modeling, designing and operating the communication networks.

In the work herein we have carried out the analysis of real M2M traffic, which allows specify its properties and characteristics, elaborated the model of the incoming traffic’s short-term forecasting. The offered methodology might be used further upon analysis of M2M traffic, formed under other conditions with other type devices.

At the first stage, there has been organized serving with LoRaWAN signals of the country's biggest cities: Almaty, Nur-Sultan, Shymkent. About a hundred base stations were installed. Hardware and software have been developed and produced by Kazakhstan company "Orion System".

Currently, in Almaty, Nur-Sultan and Shymkent the LoRaWAN networks maintain remote collection of readouts from various instrument gages. In future "Kazakhnelecom" plans to install attached sensors at the parks for tracing free places, at street lighting systems for electricity saving, monitor water level in the rivers, conditions of drain covers.

Literature analysis. To research the M2M traffic service process by mobile network, its impact at maintenance quality indices, there is used mathematical modeling. Its integral part is M2M traffic model. The work [4] offers the model and algorithm of data traffic aggregation 5G Network Slicing medium, based on classification and measurement of data traffic to maintain the service quality for smart systems in the city's intelligence medium. For modeling the traffic in the M2M network the researches in [5, 6] apply ON/OFF process. It is assumed, that M2M devices might be in one of four states: OFF, PU, ED and PE. In the state PU, ED and PE there transferred the batches, consequently, there starts the process ON. When batches are transmitted neither from, nor to the corresponding machine, there starts the process OFF. It matches the satiation, when the device is in the wait state. Whereas the M2M communication has multitude of application scenarios, its possible usage in smart networks has been discussed in the article [7]. Modeling outcomes show that occurred delays considerably increase upon corresponding growth of smart meters' amount.

One of the steps, directed to M2M traffic maintenance methods upgrading, is constructing the model, which would allow fulfill traffic prediction in short-time period and match the majority of modern mass applications of M2M devices. There are known models, making use of neuron network technologies apparatus [9], theory of Markoff processes [8], statistical modeling methods [8], etc. Universal model, which could be used for M2M any type forecasting has not been designed by the time being. In our work we have made an attempt to design the model, based on one of time series analysis methods – exponential smoothing method with smoothing parameter value selection. For the traffic type under study the model thereof provides satisfactory prediction outcomes. Let's consider the model elaboration process on the real example.

Analysis of real traffic and prediction. One telecommunication company in Almaty city carries out the traffic monitoring in the LoRa WAN network. There have been collected the data on real M2M traffic, incoming fromM2M devices to network server of LoRa WAN network. The traffic is measured in bit/s. Data were collected within 12 hours. Readings were taken about the amount of traffic received every 15 minutes. Thereat, 48 traffic values have been analyzed.

Data graphical representation is given in the figure 1 in the form of time series.

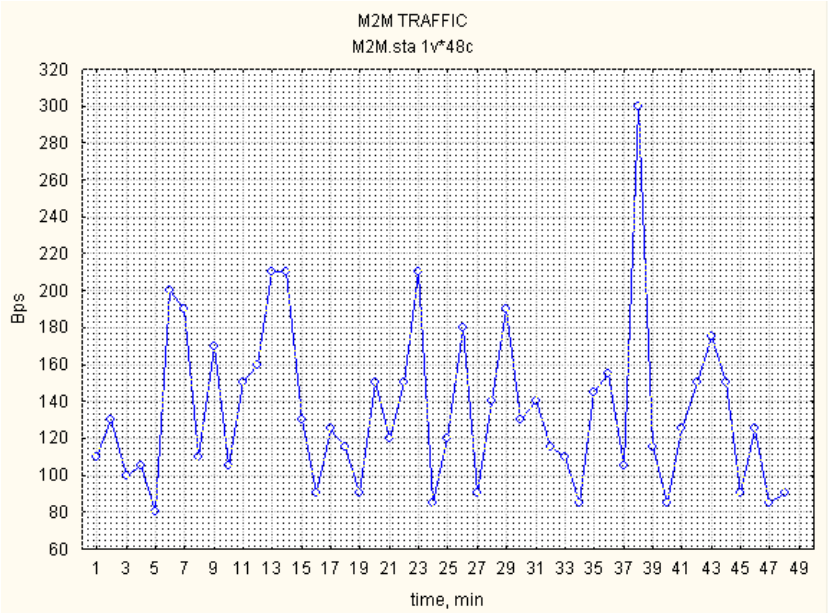

Figure 1 – M2M traffic dynamics

To define the real M2M traffic self-similarity extent let's evaluate Hurst parameter by R/S statistics method. There exist plenty of Hurst parameter assessment methods, which is a complicated task. Upon researching really measured traffic the following problems should be taken into consideration [20].

For measured real M2M traffic, presented in figure 1, there have been obtained the following values log(N/2) and log(R/S), which are given in table.

Let's define Hurst parameter H = 0,47, applying technique of least squares.

For traffic prediction there has been used exponential smoothing method, which is one of routine methods, employed upon some series forecasting.

Values of R/S standardized range

log(N/2)	log(R/S)
1,38	0,57
1,08	0,53
0,78	0,48

Method of time series exponential smoothing assumes establishing the initial series different weight levels which are preliminarily multiplied by corresponding coefficients. The later levels of the series are provided with bigger weight, and previous levels are multiplied by weight coefficients of less value. Levels weight reduction takes place along the exponent, dependent on the value of smoothing parameter, being in the interval from 0 to 1 [10].

Simple exponential smoothing is fulfilled according Brown method. At availability of the trend constituent there is applied Holt method. If the series includes a trend and stepping constituent, there is applied Vinters method.

As the time series of M2M traffic values do not contain the trend and stepping constituent, there has been employed Brown method (simple exponential smoothing).

We have accomplished the short-term prediction of M2M traffic for 1-4 periods (15-60 minutes) beforehand, as there was of paramount importance the prediction for the time period within one hour.

Considering, that the smoothing parameter's value is not known in advance, there were being constructed the prediction models with different parameters and selected the model amongst them, providing the most accurate prediction. Smoothing was fulfilled at smoothing parameters' values: a = 0,1, a = 0,5 and a = 0,9.

As far as the sampling contains 48 data, the forecast has been computed for 49, 50, 51 and 52 15-minutes time periods.

Graphical interpretation of conducted calculation is shown in the figure 2.

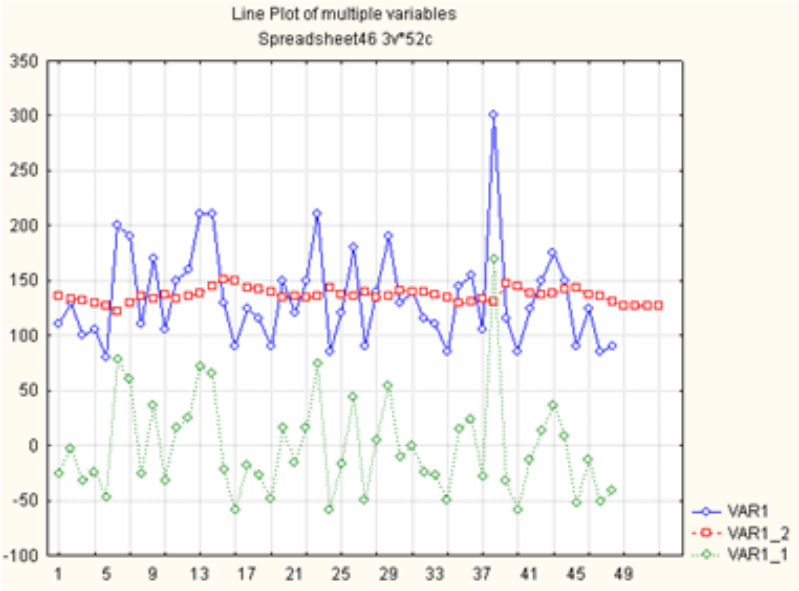

Figure 2 – Graphic representation of exponential smoothing process at a = 0,1

In figure 2 the curve VAR1 images the initial time series, VAR1_2 – exponentially smoothed series with predictive estimates. VAR1_1 shows the difference between the initial and smoothed series levels.

To assess the prediction accuracy in STATISTICA packet there have been calculated a number of error types, obtained upon constructing prediction models (figure 3).

Summary of error	Exponential smoothing: S0=135,2 (M2M.sta) No trend,no season; Alpha= ,100 VAR1 **Error**
Mean error	-1,697062711
Mean absolute error	36,224091610
Sums of squares	100188,469352625
Mean square	2087,259778180
Mean percentage error	-11,027103084
Mean abs. perc. error	28,295100511

Figure 3 – Errors calculation at a = 0,1

Researches quite frequently assess the forecast accuracy, using Mean abs.perc. error (MAPE) – mean absolute relative error. At a = 0,1 MAPE value constituted 28,29. It is assumed, that at 20 < MAPE < 50 the obtained prediction is characterized with satisfactory accuracy.

In the same manner, there have been conducted computations of the traffic predicted values by means of exponential smoothing method at other values of smoothing parameter.

Graphic representation of the process modeling at a = 0,5 is given in figure 4. Figure 5 presents modeling calculated errors.

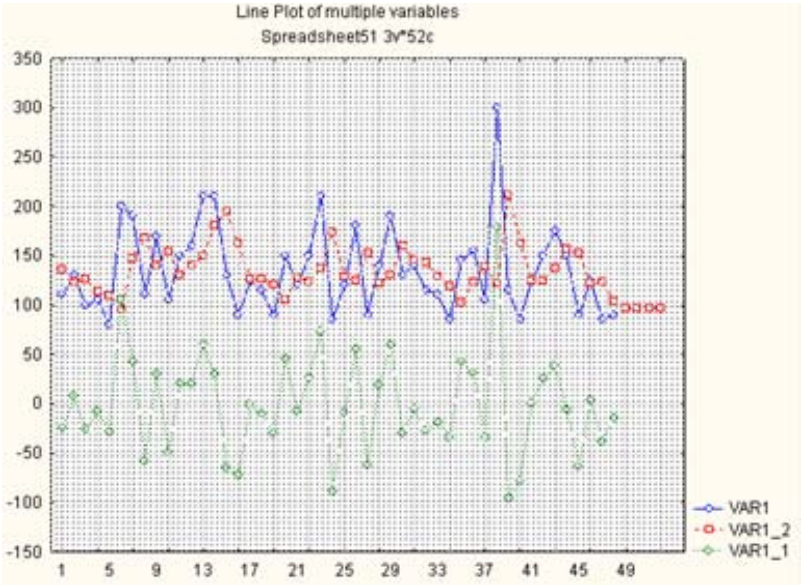

Figure 4 – Graphic representation of exponential smoothing process at a = 0,5

Summary of error	Exponential smoothing: S0=135,2 (M2M.sta) No trend,no season; Alpha= ,500 VAR1 **Error**
Mean error	-1,589243919
Mean absolute error	39,678932427
Sums of squares	126712,037593739
Mean square	2639,834116536
Mean percentage error	-11,048518211
Mean abs. perc. error	30,911961823

Figure 5 – Error computation at a = 0,5

MAPE error magnitude, equaled to 30,91, happened just over than at modeling with a = 0,1.

Upon constructing the exponential smoothing model with a = 0,9 in STATISTICA packet there have been obtained the following outcomes (figure 6, 7).

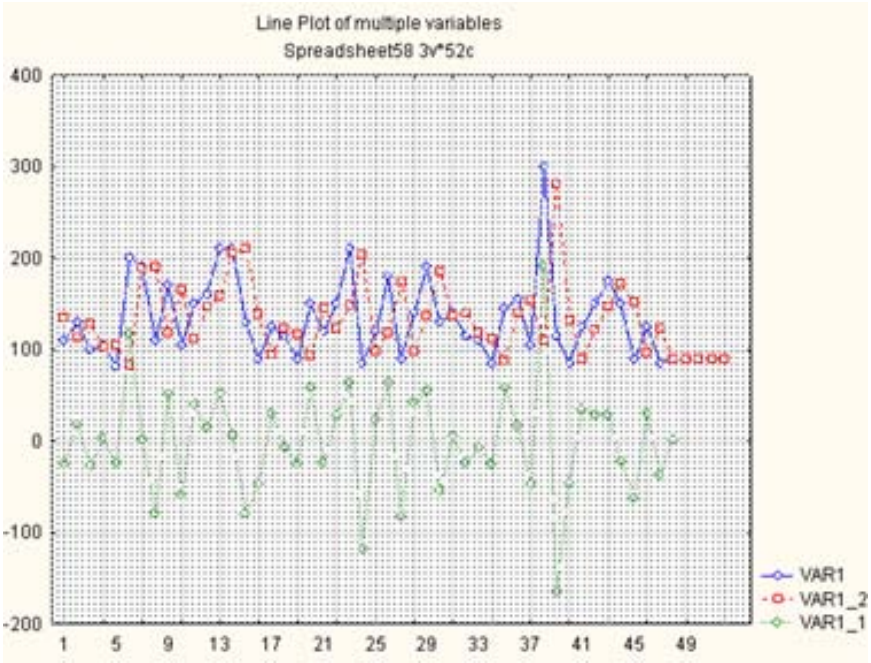

Figure 6 – Graphic display of exponential smoothing process a = 0,9

Summary of error	Exponential smoothing: S0=135,2 (M2M.sta) No trend,no season; Alpha= ,900 VAR1 **Error**
Mean error	-1,049470166
Mean absolute error	44,768216865
Sums of squares	167735,146218579
Mean square	3494,482212887
Mean percentage error	-10,263419710
Mean abs. perc. error	35,026762567

Figure 7 – Error calculation at a = 0,9

Traffic prediction for 49, 50, 51 and 52 15-minute periods composed 89,87 Bps. MAPE error value reached 35,026.

Conclusion. The modeling outcomes of M2M traffic dynamic series by means of exponential smoothing method under different smoothing parameter values were compared. It is possible to make a conclusion, that all considered models secure satisfactory forecast precision. Though, the most accurate outcome has been obtained in consequence of constructing the model with smoothing constant a = 0,1. Prediction value in that case amounted to 127 Bps, and error value of MAPE forecast turned out to be minimal and composed 28,3.

Elaborated prediction model, upon constructing of which, there has been applied Brown method, can be used in M2M networks. At that, prediction shall be fulfilled regularly upon incoming new statistical data.

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МАШИНААРАЛЫҚ ӨЗАРА ӘРЕКЕТТЕСУДІҢ (M2M) НАҚТЫ ТРАФИГІН СТАТИСТИКАЛЫҚ ТАЛДАУ

Аннотация. Машинааралық өзара әрекеттесу түріндегі қосылыстар (Machine-type Communication (MTC)) немесе "машина-машина" (M2M) қосылыстары - бұл адамдармен өзара әрекеттесуді қажет етпейтін құрылғылар арасында деректерді беру нысаны. Қосылыстардың бұл түрі интернет заттарының (IoT) болашағын қамтамасыз ете отырып, ақпараттық-коммуникациялық технологияларда маңызды рөл атқарады.

M2M құрылғылары үшін деректерді берудің ең тиімді ортасы-ұялы байланыс. Ұялы байланыс желісіндегі M2M машинааралық трафиктің тез өсуі зерттелетін мәселенің өзектілігін, оның ерекшеліктері мен сипаттамаларын анықтайды. Зерттеу нәтижелері желілік модельдеу, жоспарлау, M2M трафигінің мобильді желінің қызмет көрсету сапасына (QoS) әсерін талдау үшін қажет.

Мақалада LoRaWAN желісіндегі нақты трафик талданады. Барлық құрылғылардан желілік серверге кіретін біріктірілген трафик қарастырылады. M2M пакеттік трафигін модельдеу үшін статистикалық сипаттамаларды көрсетумен қатар, оның өзіндік ұқсастығын бағалау қажет. Трафиктің өзіндік ұқсастығын анықтау үшін Херст параметрі есептелді. STATISTICA бағдарламалар пакетінің негізінде статистикалық талдау және экспоненциалды тегістеу әдісімен M2M нақты трафигін қысқа мерзімді болжау жүргізілді.

Түйін сөздер: заттар Интернеті (IoT), M2M трафигі, мобильді байланыс желісі, Херст параметрі, болжау, статистикалық талдау.

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СТАТИСТИЧЕСКИЙ АНАЛИЗ РЕАЛЬНОГО ТРАФИКА МЕЖМАШИННОГО ВЗАИМОДЕЙСТВИЯ (M2M)

Аннотация. Соединения в виде межмашинного взаимодействия (Machine-type Communication (MTC)) или соединения «машина с машиной» (M2M) представляют собой форму передачи данных между устройствами, которая не обязательно требует взаимодействия с человеком. Этот тип соединений будет играть важную роль в информационно-коммуникационных технологиях, обеспечивая будущее Интернета вещей (IoT).

Наиболее эффективной средой передачи данных для M2M устройств является мобильная связь. Стремительный рост межмашинного трафика M2M в сети мобильной связи определяет актуальность исследуемой проблемы, ее особенности и характеристики. Результаты исследований незаменимы при сетевом моделировании, планировании, анализе влияния трафика M2M на качество обслуживания (QoS) мобильной сетевой связи. В статье анализируется реальный трафик в сети LoRaWAN. Рассматривается агрегированный трафик, поступающий на сетевой сервер со всех устройств. Для моделирования пакетного трафика M2M помимо задания статистических характеристик необходимо оценить его самоподобие. Для определения самоподобия трафика был вычислен параметр Херста. На основе пакета программ STATISTICA проведен статистический анализ и краткосрочное прогнозирование реального трафика M2M методом экспоненциального сглаживания.

Ключевые слова: интернет вещей (IoT), трафик M2M, сеть мобильной связи, параметр Херста, прогнозирование, статистический анализ.

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