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SUBSYSTEM OF CPS INFORMATION SUPPORT ORGANIZATION

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Abstract: **The possibilities of the information support for cyber-physical designing systems have been considered. Their coincidence with Open System Interconnection Standard has been analyzed. Their effectiveness has been taken into account. From this point of view, the usage of compression technique, low-energy wireless networks has been considered.**

Index Terms: **Wireless network, cyber-physical system, entropy, compression technique, information support subsystem.**

I. INTRODUCTION

Industry 4.0 (commonly referred to as the fourth industrial revolution) is defined as the digital transformation of manufacturing, leveraging third platform technologies, such as Big Data/Analytics and innovation accelerators, such as the (Industrial) Internet of Things; and requiring the convergence of Information Technology (IT) and Operational Technology **(**OT), robotics, data and manufacturing processes to realize connected factories, smart decentralized manufacturing, self-optimizing systems and the digital supply chain in the information-driven cyber-physical environment. Decentralized intelligence helps create intelligent object networking and independent process management, with the interaction of the real and virtual worlds representing a crucial new aspect of the manufacturing and production process what has been called a "smart factory". There is corresponding with the current trend of automation and data exchange in manufacturing technologies. It includes cyber-physical systems, the Internet of things, cloud computing and cognitive computing. Within modular structured smart factories, cyber-physical systems monitor physical processes, create a virtual copy of the physical world and make decentralized decisions. Over the Internet of Things, cyber-physical systems communicate and cooperate with each other and with humans in real-time both internally and across organizational services offered and used by participants of the value chain [1]**.**

The initial goals in Industry 4.0 typically are automation, (manufacturing) process improvement and productivity/production optimization; the more mature goals are innovation and the transition to new business models and revenue sources with information and services as cornerstones. In many senses it is related to the Industrial Internet. Smart industry refers to the technological evolution from embedded systems to cyber-physical systems [2], [3].

A cyber-physical system (CPS) is a mechanism that is controlled or monitored by computer-based algorithms, tightly integrated with the Internet and its users. In cyber-physical systems, physical and software components are deeply intertwined, each operating on different spatial and temporal scales, exhibiting multiple and distinct behavioral modalities, and interacting with each other in a lot of ways that change with context. Examples of CPS include smart grid, autonomous automobile systems, medical monitoring, process control systems, robotics systems, and automatic pilot avionics.

CPS involves transdisciplinary approaches, merging theory of cybernetics, mechatronics, and design and process science. The process control is often referred to as embedded systems. In embedded systems, the emphasis tends to be more on the computational elements, and less on an intense link between the computational and physical elements. CPS is also similar to the Internet of Things (IoT), sharing the same basic architecture; nevertheless, CPS presents a higher combination and coordination between physical and computational elements.

Unlike more traditional embedded systems, a full-fledged CPS is typically designed as a network of interacting elements with physical input and output instead of as standalone devices. The notion is closely tied to concepts of robotics and sensor networks with intelligence mechanisms proper of computational intelligence leading the pathway. Ongoing advances in science and engineering will improve the link between computational and physical elements by means of intelligent mechanisms, dramatically increasing the adaptability, autonomy, efficiency, functionality, reliability, safety, and usability of cyber-physical systems. This will broaden the potential of cyber-physical systems in several dimensions, including: intervention (e.g., collision avoidance); precision (e.g., robotic surgery and nano-level manufacturing); operation in dangerous or inaccessible environments (e.g., search and rescue, firefighting, and deep-sea exploration; coordination (e.g., air traffic control, war fighting); efficiency (e.g., zero-net energy buildings); and augmentation of human capabilities (e.g., healthcare monitoring and delivery).

Some kind of CPS is a mechatronic system that involves a set of sensors, conditioners of sensors' signals, processing and decision-making unit and actuator [3]. Combination system software and hardware with Internet as a communication link give us a cyber-physical system.

It connects embedded system production technologies and smart production processes to pave the way to a new technological age which will radically transform industry and production value chains and business models (e.g. "smart factory").

It is the next phase in the digitization of the manufacturing sector, driven by four disruptions: the astonishing rise in data volumes, computational power, and connectivity, especially new low-power wide-area networks; the emergence of analytics and business-intelligence capabilities; new forms of human-machine interaction such as touch interfaces and augmented-reality systems; and improvements in transferring digital instructions to the physical world, such as advanced robotics and 3-D printing [4].

Cyber-physical systems are combinations of intelligent physical components, objects and systems with embedded computing and storage possibilities, which get connected through networks and are the enablers of the smart factory concept of Industry 4.0 in an Internet of Things, Data and Services scope, with a focus on processes. Simply put, as the term indicates, cyber-physical systems refer to the bridging of digital (cyber) and physical in an industrial context.

Cyber-physical systems in the Industry 4.0 view are based on the latest control systems, embedded software systems and an IP address. The presence of an IP address means that cyber-physical systems, as objects, are connected to the Internet (of Things). An IP address also means that the cyber-physical system can be uniquely identified within the network.

There is an integration of computation with physical processes. Embedded computers and networks monitor and control the physical processes, usually with feedback loops where physical processes affect computations and vice versa. As an intellectual challenge, CPS is about the *intersection*, not the union, of the physical and the cyber. It is not enough to separately understand the physical components and the computational components. One must instead understand their interaction. The design of such systems, therefore, requires understanding the joint dynamics of computers, software, networks, and physical processes.

Function of the multichannel system

Multichannel measurement tool is the mutual main information link in the control circuit of the object of measurement, which assembles processes and communicates information about this object. Implementation of measures on personnel safety, reliability of the operation of the facility, the lack of sufficiently complete a priori information about external influential factors, the need for the fullest possible effectiveness of the research and payback of invested funds, demands more and more flexibility in the work of the facility. There is a tendency to the complexity of research objects, the growth of the number and variety of measurement programs, mostly the remoteness of the objects under study from the control centers, the lack of bandwidth of the communication lines.

Along with servicing objects that work in typical (so-called, regular modes), one can identify tasks of studying the behavior of objects, phenomena and processes. These means are intended to automate the process of scientific research as a measuring task of complexity. The cost of measuring instruments is approaching the cost of controlled equipment. Although today you can carry around 100 million measurements per second but almost cannot use only (5–10) % data received from the object [5]. The need for processing large part of measurement information directly near its place of occurrence imposes several restrictions measuring device related to saving energy, storage and recording of storage facilities, power computational algorithms, weight and dimensions of the used equipment.

The above factors determine the need to increase the autonomy of the information support tool, formulate fundamentally new requirements for the organization of operational, rational and purposeful collection, processing and exchange of significant and continuously growing arrays of information, operational evaluation of the state of the object of study, a management of the measurement experiment. These trends are calling computing complexes equipped with one or more specialized or versatile machines that can communicate with remote subscribers of the measuring and computing network. Such a network uses measurement information from a digital multichannel measuring instrument that serves a set of measuring information sources and uses only one communication line to connect the transmitting and receiving parts of the medium. It is known that when designing and testing multichannel measuring instruments, it is necessary to choose the appropriate method of compression and separation of channels [6], [7]. For the most part, the number of sealed channels in the media is significant (it may be several thousand), the most of sources of measurement information are analogue and the means themselves – digital (facilitating connectivity with digital computers and networks).

Among the linear methods of compaction by the advantage of frequency and form, compared to the time, there is the possibility of simultaneous operation of several channels. However, when frequency separation does not provide sufficient flexibility in the build-up of the medium or the change in its structure and the bandwidth of communication channels is not sufficiently used [6], [7].

Significant curiosity between nonlinear methods is the logical sealing, which uses channel signals, the functions of Rademacher-Walsh, and the nonlinear formation of a group signal [7]. The promise of the method is due to the fact that the generation and processing of these functions are easily realized on the standard digital circuits of the modern element base, it is flexible at increasing the means, provides increase of its noise immunity at decrease of activity of sealing sources due to decrease of level of inter-channel noise, however, the speed of the generator of channel signals depends on quantity sources of the object of measurement. The theory of such sealing is still not sufficiently worked out. Consequently, among the various methods of sealing and separating channels, the time division is dominant.

Obviously, information-gathering support subsystem is realized as multiplex time division systems. Totality sources set are shared in the different areas of human activity such as scientific research, astronautics, agriculture, space investigation; image processing etc. is served by multiplex time division systems. There are data monitoring systems for health care which simultaneously monitor, transmit by radio data records relating to a plurality of physiological parameters, comprising a portable sensor unit, which is worn by the patient and includes plurality of sensors attached to the patient's body, each of which monitors a physiological parameter and generates a corresponding electrical signal, a circuit pack, which converts the signals into a series stream of digital data and a transmitter, which periodically transmits the data. A base station includes both a receiver, which receives the transmitted data and reconverts it to a digital signal and a data processing unit which records the data. In the research field of several biomedical disciplines a major need exists for reliable and implantable telemetry sensor systems. Apart from the demands for small size, light weight and long operational lifetime, the sensor systems should preferably also be flexible, versatile and intelligent [8].

Nowadays, sensors with output analog signals are very shared and the multichannel systems designed on the time division principle are based on the Shannon sampling theorem using [9]. Sampling interval of a sensor signal is corresponded with both signal frequency properties and desired error of analog signal renovation at the receiver side. Often, partly stationary zero-mean random process as every signal mathematical model is taken. Any stationary interval differs from another by the frequency properties, which are corresponded with the form of correlation function or its parameters values.

The regular type system sampling time is corresponded with the highest frequency of the source signal spectrum and total sources frequency properties are satisfied as well. However, the channel capacity is using effectively only at the real and a priory suspecting object state coincidence. So, there is a certain redundancy of the system sources totality data stream [10]. The redundancy measure depends on the consumer desired precision, valid probability value or renovated analog processes quality. It was found that at any given time, only a fraction of the neurons was active, therefore it was possible to reduce data by 97%. Thus, it is necessary to use some possibility compression techniques.

Traditional measurement tools with a regular survey of a set of sources are not able to meet the above requirements. For these devices, a significant redundancy of measuring signals is characteristically shown. Studies show that many of the measured parameters change not only the parameters of correlation dependencies, but also their involvement in their different classes. This circumstance makes it difficult for a cyclic sampling of sources, coordinated with non-stationary spectrum of processes. Similar problems are arisen by other means created both for the measuring experiment and for staffing of modern objects. Along with this, the task of reducing the power of measuring signals (especially it is actual task in the conditions of the autonomous operation of the objects of measurement) remains the urgent one, requirements to the speed of processing of the measurement information, while observing the accuracy of the reproduction of the measuring signals. Therefore, nowadays, considerable attention is paid to the methods of adaptation of the means as to the conditions of communication, connected with the change in the intensity of noise [6], and to the flow of measurement information processed by the proper means. The adaptation to the flow of measurement information, which will reduce both statistical and semantic redundancy has been analyzed. The first one uses compressing methods [11], and the second – alternate sets of survey programs [12].

Different ways of redundancy minimizing are used, i.e., neural networks, wavelet, fuzzy, prediction and other compression techniques [13], [14], [15]. Nowadays, it is very popular compressive sensing [16]. The novel theory of compressive sensing provides a fundamentally new approach to data acquisition, which overcomes this common wisdom. It is predicted that certain signals or images can be recovered from what was previously believed to be highly incomplete measurement information. It is the way to have convenient size of transmitted data, which is efficient from the data rate point of view. It is another important feature of compressive sensing that practical reconstruction can be performed by using efficient algorithms. Since the interest is in the vastly under sampled case, the linear system describing the measurements is underdetermined and therefore has infinitely many solution.

They are actively used in different applications. Mainly such compression relies on the convenient base. Space data compression has been used on deep space missions since the late 1960s. Data compression may be viewed as a branch of information theory in which the primary objective is to minimize the amount of data to be transmitted. A simple characterization of data compression is that it involves transforming a string of characters in some representation into a new string (of bits, for example) which contains the same information but whose length is as small as possible. Significant flight history on both lossless and lossy methods exists. NASA proposed a standard that addresses most payload requirements for lossless space data compression the applicable criteria that follow.

Such compressive techniques as adaptive switching, polynomial prediction or interpolation are often used [11]. Having decreased redundancy, the adaptive representation of a set of parameters generates the emergence of a total flow of samples, the randomness of which manifests itself in the chaotic flow of them from different sources of measurement information (hence, the need to identify the counters of individual sources), and in case of accidental moments of occurrence of messages in means with prediction (interpolation). The need for additional service information somewhat reduces the efficiency of compression of measurement information and at certain frequency properties of a set of sources can completely level it.

The aim of data compression is to reduce redundancy in stored or communicated data, thus increasing effective data density. Data transmission, compression and decompression of data files for storage is essentially the same task as sending and receiving compressed data over a communication channel. Compressive sensing is a new type of sampling theory, which predicts that sparse signals and images can be reconstructed from what was previously believed to be incomplete information.

Data compression algorithms encode all non-redundant information with the minimal number of bits required for reconstruction. To have right process renovation it is necessary to use the additional service information such as a source identification (address) and time marking. Therefore, for some source frequencies properties compression procedure has no effect [17]. To solve these problems there are designed flexible programmable multiplex time division systems [18], [19]. A proper regular type system sampling program depends on this set of a priory known or estimated activities. When the measuring object state a priory is known well enough, the programmable system serves it satisfactory.

Consequently, a modern multichannel, measuring-information complex or network should optimize its algorithm, in particular, survey programs, source kits in accordance with the current situation on the measurement object. Given the actual partly stationary nature of the studied processes, it may be possible to simplify the creation of a set of programs adapted to different correlation links of these processes, minimizing the average risk when applying the quadratic function of losses (fines), which allows to minimize the variance of the error of recovery of continuous functions. It is possible to form survey programs, using the method of dynamic programming. In these programmable means of measurement, several decentralized local switches located near the sources of measurement information; the frequency of which polls varied according to the finite number of programs recorded in the memory of the means was used. The choice of a program (the number and set of service sources, polling rates) was carried out both by external commands and by signals generated by the means themselves. This allowed to partially adapt the means to change the operating conditions, which were determined by changing the bandwidth of the communication channel.

Sensors set which are checking behaviors of object parameters reflect an object state. A proper regular type system-sampling program depends on this set of a priory known or estimated activities. If the object states a priory is poor known, it needs sampling program adaptation to the current object situation. These properties are discovered by every ***i***-th source activity manifestation. It is typical for remote investigated objects, i.e. the deep space invention instrumentation or dirty territory serving. In this case, the intelligent multiplex system implantation is considered as well operating and the intelligent measurement instrumentation functions should be extended by the implantation of the task of the observed object state identification, the inspected parameters real activities to the adopted sampling program adequacy learning and, in this sense, the external situation registration. Apart from the demands for small size, lightweight and long operational lifetime, the sensor systems should also be preferably flexible, versatile and intelligent.

Flexible change of the tool operating was provided by the main-modular principle of construction, in which separate functional modules had cross-links between themselves through the information line. Optimization of programs of non-cyclical service with the help of the deterministic variant of the method of dynamic programming with unlikely combinations of disturbing factors is not effective. Consequently, most of the practically realized means were provided with certain sets of a priori known programs, designed for pre-predicted situations. The impossibility of adapting the program to emergency situations caused by unplanned modes of operation of various object modules is a significant disadvantage of such a survey. The stochastic formation of an optimal program by dynamic programming methods allows us to solve the problem only approximately. If you select a target function in the form of average losses, then finding the optimal solution becomes even more complicated, even for a priori known distributions of measured parameters. This method, strictly speaking, is not quasi-reversible, since it does not guarantee the specified accuracy of the restoration of each individual parameter, but only the average error of the recovery of all sources of the population. However, providing a reduction in the redundancy of the measurement information of some of the sources of the measurement object can be classified as a not adaptive compression method.

To reduce the amount of digital information that a multichannel uses, often the difference representation is used, as well as the feasibility of combining adaptive discretization and difference representation also is considered [20].

Practically in all areas of human activity there are situations in which it is necessary to rationally make a decision, that is, to choose from a plurality of options in a sense the best. Often, for measuring instruments, the target function is the required speed of digital processing of measuring signals, and the task is to reduce the requirements for the bandwidth of communication channels while ensuring the appropriate accuracy of reproduction of the processes maintained and economical use of energy resources. An expression was found to determine the energy threshold of the sensitivity of the measuring instrument. The integral property of the signal strength as a generalized characteristic of the behavior of the processes which they reflect was noted, however, the possibility of exchange between the power of the measuring signal and its duration with respect to the constancy of the signal energy was not studied in detail.

In recent years, multichannel time-division measuring devices adaptively adapted to the flow of information have been actively designed to allow more economical usage of the available bandwidth of the communication channel, memory capacity, lower computing power requirements, and reduce energy costs compared to conventional systems of regular service. For the most part, such digital systems are analyzed when servicing analog sources of measurement information, and at the same time they evaluate the error of the restoration of the process under investigation on the receiving side of the system. At the same time, the chaotic appearance of non-redundant sample values requires their numbering, which reduces the adaptive efficiency and, the smaller the activity of the aggregate of sources and the greater number of them, therefore, it is worth finding the criterion of the appropriateness of adaptation. Often, the size of the identification part of the count does not depend on the activity of the source of information and is excessive. It is possible to reduce its specific weight in the structure of the codeword if it is used instead of the individual-group numbering methods, the distortions of which, however, have a more significant effect on the quality of analog signal restoration.

II. OBJECT STATE ENTROPY ESTIMATION

The concrete combination of addresses of significant samples of active sources may be some generalized image of the study object. It can be used as information for the control function of next level of the cyber-physical system as well. If is used for source identification an individual address, then it is encoded by primitive binary code. In this case, it would require $\log_2 n$ binary digits (here – n is the number of sources of measuring information). There is a paradoxical situation: on the one hand, adaptive maintenance reduces information redundancy of system measuring information because of providing the real aggregate activity sources. However, the cost of service information by using individual addresses made it worse. The group of non – redundant samples addressing promise the better results. For the task, the permutation group code [21] may be used, because its number of symbols per one sample is close to the entropy of active sources totality. While using primitive coding for individual source address corresponds with the same activity of each source, i.e., equal to maximum entropy of sources totality (equiprobable sources). Both permutation coding and entropy measure is often effectively used for wireless networks, dynamic and other systems, especially for biometric usage, creation [22], [23]. For example, body wireless network uses an intrinsic characteristic of the human body as the authentication identity or the means of securing the distribution of a cipher key to secure inter – body area sensor network communications. The relationship between a novel personal entropy measure for online signatures and the performance of several state-of-the-art classifiers was studied and it showed that there is a clear relationship between such entropy measure both of a person's signature and the behavior of the classifier. Currently, almost all systems involve an identity authentication process before a user can access requested services such as online transactions, entrance to a secured vault, logging into a computer system, accessing laptops, secure access to buildings, etc. Therefore, authentication has become the core of any secure system, wherein most of the cases rely on identity recognition approaches. Biometric systems provide the solution to ensure that only a legitimate user and no one else access the rendered services. The information content of the haptic data generated directly from the instrument's interface was analyzed. It was successfully applied to cryptography needs. For some well-known chaotic dynamical systems, it is shown that its complexity behaves particularly well described by entropy measure in the presence of dynamical or observational noise. It was shown that the metric and permutation entropy rates — measures of new disorder per new observed value — are equal to ergodic finite-alphabet information sources (discrete-time stationary stochastic processes). Finally, the equality of permutation and metric entropy rates is extended to ergodic non-discrete information sources when entropy is replaced by differential entropy in the usual way. Amplitude quantization and permutation encoding are two approaches to efficient digitization of analog data. The recently proposed conceptually simple and easily calculated measure of permutation entropy can be effectively used to detect qualitative and quantitative dynamical changes. It was proposed both to use entropy measure for information object state examination and proper algorithm creation [24].

Since the measurements are not carried out for the sake of the measurements itself, but are subordinated to the specific purpose of a specific measurement experiment, certain conclusions and actions will be formed on the basis of its results; however, the coincidence of the information characteristics of the multichannel facilities and the object of measurement is not still analyzed. In particular, both in experimental studies and in regular operation, there is a need for rapid analysis, that is, in obtaining operational information about the general information status of the object. An adaptive tool can be the main information tool for performing such a task.

III. COINCIDENCE OF THE MULTICHANNEL MEASUREMENT TOOL WITH OPEN SYSTEM INTERCONNECTION STRUCTURE

The multichannel tool, as a component of the measurement and computing network, fits well into the structure of the reference model of open OSI systems [25]. According to the terminology of this model, the problems of designing multichannel means are identified with the tasks of the level of applied processes, and the results of the analysis of the means can serve as the source information for solving the corresponding tasks at the levels of data transmission and physical (Fig. 1).

It is known [26] that the informativity of an object is determined by its entropy. The provisions of the theory of information [27] are increasingly used in technology: first, in assessing the capabilities of information transmission channels (in particular the measuring) [9], then – to evaluate the errors of the measurement experiment, introduced the concept of entropy error, the information ability of the device [28], and other measuring procedures.

There are open questions concerning multi-channel means on the expediency of forming an information evaluation of the state of an object through its entropy [29]. The adaptive principles of organizing the work of the tool contribute to solving of this problem, because having observed, over a certain period of time, the behavior of the aggregate of the sources of the object of measurement, it is possible to gain a certain statistic of their information activities, on which to estimate the entropy of the activity of a set of sources, reflecting the information state of the object's measurement. It turns out [30] that when grouping a set of references by repositioning codes, it is possible to form the current evaluation of the information status of the object. By the way, the state number is a scattered image of the totality of measurement results. However, possible distortion of the group number by interruptions in transmission over the communication line may have more negative effects for reproducing the measured parameters than the damage to the individual number. Note that the number of bits used for individual numbering corresponds to the maximum value of the entropy of a set of sources, that is, their equal activity, which is practically unlikely. Often, it is necessary to store an array of selective values, reducing the volumes used when they form binary symbols with a different representation. The application of such a more economical representation is possible due to a certain correlation of significant selective values of each of the sources.

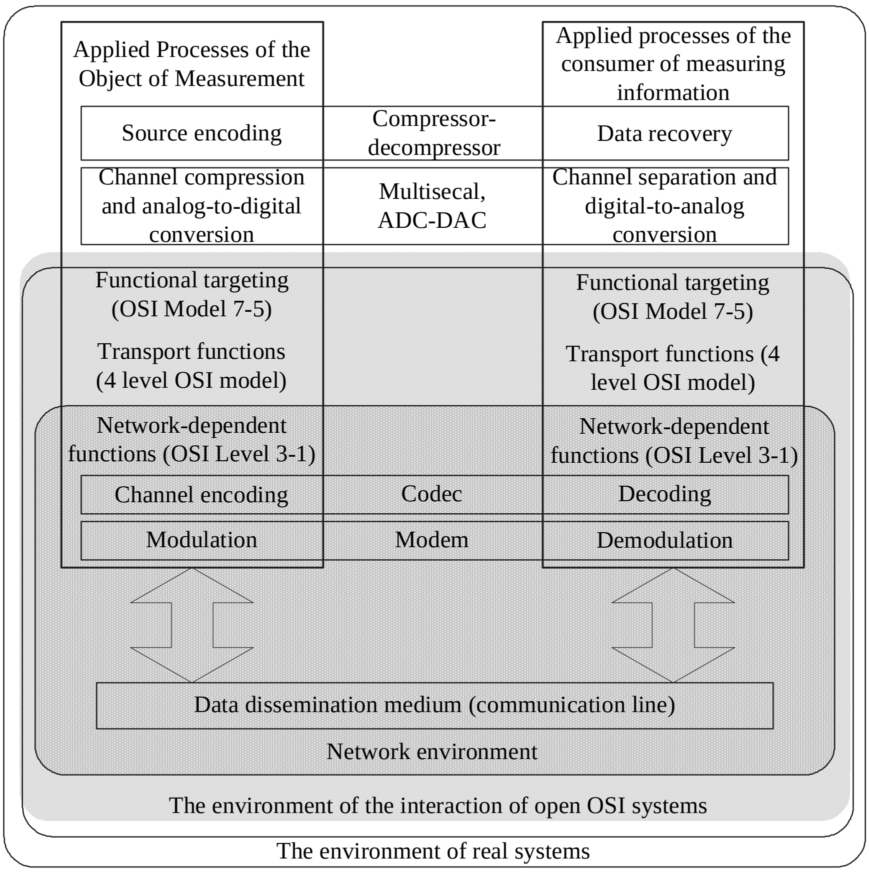

Fig. 1. Multi-level model of interaction of open systems

The method of time division of channels with the address identification of active sources, despite the impossibility of simultaneous operation of several channels, is perspective because of its simplicity and flexibility when building the system or changing its structure [7]. The procedures for converting the measuring signals of the multichannel measurement instrument can be presented as a set of subsystems (Fig.2.).

"Source-consumer" subsystem, which consists of a source formed by the physical environment of the investigated object, which changes its state, creating a message, the electric-physical converter (sensor), which forms the electrical reflection (analogue) of the message (the primary signal), and the consumer, which most frequently is a recording device (tape recorder, graphics installer etc.) or a presentation device (display, oscillator and speaker).

"Source coder" subsystem contains a source encoder designed to convert the primary signal into a sequence of electrical signals corresponding to the symbols of the code used (for example, binary), eliminating the natural redundancy of the measurement information so that their number per unit time will be minimal, and the source decoder that performs the inverse transformation.

"Multiplexing and dividing" subsystem covers a channel multiplexing device, which generates a group signal from a set of converted primary signals of measurement information sources and service signals (including address parts) in such a way as to ensure, with the necessary probability (with a low level of inter-channel interference), the possibility of separating from group primary (channel) signals, and a channel separation device, which provides for the allocation of primary signals in the receiving part of the system.

The subsystem "channel codec" encompasses a channel encoder, with the aid of which, in accordance with known laws, the selective redundancy is introduced into the group signal, which provides noise-resistant (correcting) encoding, and the channel decoder, which, according to the functional dependencies between the code symbols, detects and corrects those positions of the group signal that is distorted by noise in the path "output of the carrier signal modulator – the input of the decoder of the channel", providing the necessary probability of transmitting the group signal in response to these interferences.

The subsystem "modem of the communication link" covers the generator, modulator and demodulator of the carrier signal, which provide the transmission of the group signal to the optimal carrier signal for the projected system, as well as the most appropriate method of modulation – demodulation.

Subsystem "propagation environment" includes an amplifier output power signal, transmitter, the actual propagation medium, receiver, providing the necessary energy relations with the effect of interference in the communication line.

The "synchronization" subsystem includes the clock and receiver synchronization device. It is intended to ensure the coordination of system devices (demodulator, channel decoder, channel division subsystem devices, source decoder, etc.), providing the necessary restoration accuracy.

The subsystem "feedback channel" consists of a transmitter and a receiver of the feedback channel, which provides a resolving or informational feedback characteristic of systems adapted to change the conditions of distribution of measuring signals.

On the formation of a mathematical model of real processes, the results of measurements significantly affect the uncertainty, lack of detail and ambiguity of the real situation. Uncertainty has recently been identified with the coincidence of certain events, in the simulation of which the apparatus of probability theory and mathematical statistics is used. The elimination of ambiguity and lack of precision became possible due to the introduction of the concept of fuzzy sets [31], which allowed to describe the ambiguous situation. The problem of decision-making in such an unpredictably formulated situation was facilitated by the introduction of the concept of a fuzzy environment, which helped to formulate one-and multi-step decision-making in such conditions. Finally, the notion of a probabilistic set was synthesized, which united the concept of uncertainty and fuzziness. These fundamental works provoked an avalanche of theoretical and applied publications on this issue. More and more contemporary design technologies – the theory of neural networks [32] and expert systems [33] are used in designing systems. The emergence of automated design systems and automated systems of scientific research [34], covering man-machine systems (so-called big systems), and designed to increase the efficiency of intellectual work, provoked the search for regularities of constructing large systems first on a heuristic (intuitive basis), and subsequently the mathematical apparatus on the basis of the abstract algebra was formulated axiomatically. Thus, along with the well-known traditional intelligence sciences such as metrology and applied mathematics, and in technical applications – system engineering and operations research [35], the theory of measurements [36], a new system theory of the structure of functioning began to emerge. Construction, organization and development of objects of automated intelligence was called "usvidmatic" ("comprehension") [37], that is, conscious, purposeful creation and production of an intelligent (functional) product.

The achievements of modern computer technology and advanced mathematical support allow more intelligent measurement tools [38], [39]. However, concrete technical systems with the independent formation of the required survey programs have not yet been proposed.

Knowledge of the surrounding world is supported by a measuring experiment, which allows to establish its regularities. The object of research can be individual phenomena, or specific physical structures, physical bodies, their states, processes that occur in them, etc. [28]. Since measurement is not an end in itself, the measurement experiment, through the installation of technical means of size, determined by the application task of a set of controlled parameters – physical quantities, helps to formulate this or that conclusion regarding the object under study.

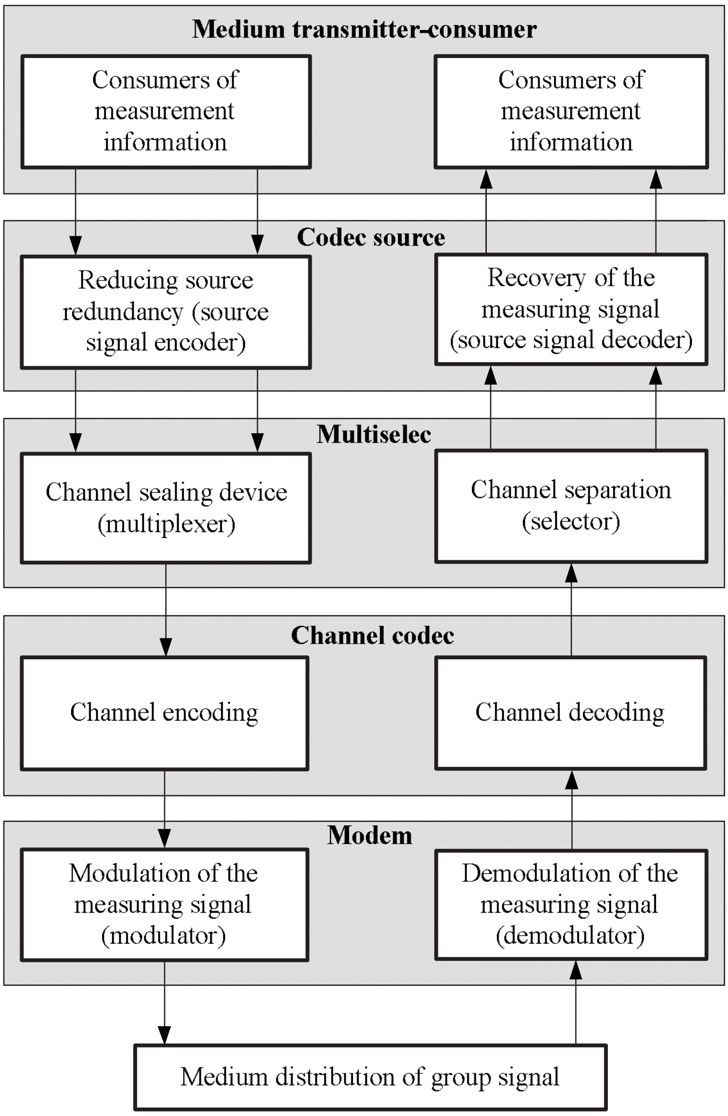

Fig. 2. The set of procedures for conversion of measuring signals

IV. MODERN TENDENCY IN COMMUNICATION

Low-power network (LPN) or Low Power Wide Area Network (LPWAN) as a type of wireless telecommunication wide area network is designed to allow long range communications at a low bit rate among things (connected objects), such as sensors operated on a battery. The low power, low bit rate and intended use distinguish this type of network from a wireless WAN that is designed to connect users or businesses, and carry more data, using more power. The LPWA data rate ranges are state from 0.3 to 50 Kbit/s per channel [40]. It may be used to create a private wireless sensor network, but can also be a service allowing the owners of sensors to deploy them in the field without investing in gateway technology. Narrowband IoT (NB-IoT) is a Low Power Wide Area Network (LPWAN) radio technology standard developed by 3rd Generation Partnership Project (3GPP) to enable a wide range of cellular devices and services [41]. The initial scope of 3GPP was to make a globally applicable third-generation (3G) mobile phone system specification based on evolved Global System for Mobile Communications (GSM) specifications within the scope of the International Mobile Telecommunications-2000 project of the International Telecommunication Union (ITU). The specification was frozen in 3GPP Release 13 (LTE Advanced Pro), in June 2016. Other 3GPP IoT technologies include eMTC (enhanced Machine-Type Communication) and EC-GSM-IoT.

NB-IoT focuses specifically on indoor coverage, low cost, long battery life, and high connection density. NB-IoT uses a subset of the LTE standard but limits the bandwidth to a single narrow-band of 200 kHz. It uses OFDM modulation for downlink communication and SC-FDMA for uplink communications.

Wireless sensory networks (WSN) covers various fields of human activity. It is caused by need of control and predict the occurrence of processes of different nature, monitoring and timely correction of the state of industrial, technical, biological objects, practically healthy people, patients of health protection institutions, athletes and sports teams, operators of man-machine complexes and systems, pilots, drivers, vehicles, protection and eco-monitoring of territories, buildings, apartments, as well as timely detection and warning of dangerous events (earthquakes, landslides, and other environmental disasters.) [42].

Widespread development of means and systems of Internet-things (IoT), industrial Internet of things, the basis of which form sensory and local-regional radio networks in the ISM-frequency range with the self-organization of the transmission of packets of information within the cells, clusters of wireless networks [43]. The implementation of effective remote monitoring requires solving a set of tasks related to processing, encoding, data transmission, evaluation and forecasting of the state of the objects of monitoring in order to prevent their threatening conditions [44], [45].

Unresolved problems in the construction of wireless means of long-term monitoring of objects, processes, events and phenomena with unlicensed use of radio channels ISM-frequency range is the implementation of reliable and secure transmission of monitoring signals and video data, taking into account the presence of significant noise in the radio channel and the use of small-sized autonomous power supplies with a small weight [46].

V. CONCLUSIONS

Multichannel systems, both with a concentrated and distributed structure, are actually problem oriented. Since based on the results of a measuring experiment, an information state of an object of measurement, the objective characteristic of which may be the entropy of the activity of the measurement sources, may be evaluated.

Quantitative evaluation of the information state of the object of measurement is associated with the use of group coding sequence of references from its sources. It is established that the use of repositioning codes for numbering of the information state of an object allows to unambiguously describe it by one number, and the number of binary symbols falling on a single count of a sequence is equivalent to the entropy of the activity of the sources of the object of measurement.

It is expedient:

1. To study the asymptotic optimality of the use of permutation coding for numbering a sequence of object sources samples a priori unknown statistics of information activities.

2. To substantiate the choice of the rational length of the sequence of N in applying the asymptotically optimal group numbering method, to optimize the sequence set.

3. Find the relationship between the information activities of the output signals of the set of measuring converters of the object and the code, which summarizes the received digital sequence of the sampled measurement signals. To form simple enough technically implemented coding algorithms – decoding sequence numbers in real time.

4. When working on an object in a regular situation, but with a priori unknown statistics, based on previous studies, to formulate a methodology for constructing an intellectualized measuring instrument.

5. To carry out simulation of proposed approaches to several types of maintenance of a set of sources of measurement information.

6. Software and hardware of low-power wireless sensor network nodes are focused on long-term offline operation with battery power and are used with the limited performance of processors, specialized devices and transmitters with minimal data transmission power. Therefore, processing, encoding and data transfer with minimization of computations are focused on software implementation by microcontrollers to determine the data entered reliability, compression of analogue signals and video data frames with the loss of insignificant information. Considering the application areas of the wireless sensor network the basis of reliable data transmission is the selection of the most informative signal samples and pixels of video frames with the subsequent accurate recovery of the amplitude-time and number parameters of analogue signals and video data.

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