Method of Improving the Information Security of Virtual Communities in Social Networking Services

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Abstract. Today, social networking services have become one of the most powerful means of mass communication between their users – actors. Social networking services are increasingly acting not only as a mean for the content exchange in the virtual environment, but also as a mean for self-organization of citizens in their real life. Therefore, on the one hand, social networking services are an objective reality of modern life, on the other hand, as the experience of many countries of the world and, first of all, Ukraine shows, is a source of threats to its information security. For example, the result of unfriendly information operations in social networking services is the manipulation of public opinion, the spread of appeals that accentuate international, interreligious and interethnic conflicts, provoke terrorism, separatism and other manifestations of violence and crimes against humanity, peace and security. The article reveals one of the methods of countering such threats. The core method is to increase the information stability of virtual communities in social networking services to destructive information influences through their hidden artificially controlled formation. The formation of information resistant virtual communities is suggested to be carried out on the basis of the critical mass principle. This approach, firstly, provides their further stable development (artificially controlled hidden increase in the number of participants) and, secondly, guarantees critical perception of the content of destructive matter. In addition, for those virtual communities that have unsatisfactory quality performance indicators, it is offered to use latent synergistic management in the form of directed information influence. The accuracy of the developed method has been proved experimentally. As a result of the study, it is found that the information stability of virtual communities in social networking services at the time of using the suggested method is higher in comparison with the natural uncontrolled processes of their creation.

Keywords: social networking service, virtual community, actor, information security, method, information stability, synergetic management, critical mass.

1 Introduction

Despite the diversification of communication channels, social Internet services (SNSs) have become the most popular segment of mass communication. At present, SNSs not only consolidate the tools for messaging and multimedia content, but also apply for the self-organization of society into virtual communities and the realization of interactions in real life. The growing popularity of SNSs is inextricably linked with the emergence of State Information Security (SIS) challenges in the information space of virtual communities. So that, SNSs are actively used by the Russian Federation to conduct a hybrid war against Ukraine. Such a form of confrontation is carried out by combining technologies of cyber impact on critical infrastructure objects and informational impact on citizens in the information space, in particular, in SNSs. The purpose of performing the information influence on the SNSs actors by the opposing party is to manipulate the personality, group of people and masses, disseminate misinformation to influence social and political processes in the state, spread chaos among the population, etc.

According to data [1] in 2018, the US Department of Justice has accused a Russian citizen of attempting to interfere with the US political system, in the midterm elections that has taken place in November. Such an intervention has been carried out using SNSs to discuss such issues as immigration, control and possession of weapons, racial relations, LGBT and women's rights march. The attackers have appeared to be American political activists, creating thousands of fake accounts in SNSs. The objectives of such actions have been polarization and the spread of antagonism in American society based on social and inter-racial contradictions, erosion of democracy and limiting the rights and freedoms of citizens.

Taking into account the growing level of threats to the national security of the world's leading countries as a result of the destructive influence of threats to information security, the European Parliament has accepted a resolution with recommendations to the EU Council and EU diplomacy focused on countering the propaganda "from Russia's side and other hostile actors" [2]. The European Parliament has recommended "to raise awareness about Russia's disinformation campaigns," which, according to the parliamentarian, is "the main source of misinformation in Europe." The European Parliament offers to develop a "legal framework, both at the union level and internationally, to counter hybrid threats, cyberwar and information war" [2].

Therefore, there is an objective contradiction between the problem of the practice of ensuring the sustainable development of the SNSs information space in the conditions of its globalization, and the increasing number of threats to the SNSs and the problem of science in developing effective approaches to counteract such threats, which guarantee a reduction of the level of destructive information influence on the SNSs actors.

2 Literature Review

Numerous studies of the specific use of SNSs actors for communicating on the Internet [3-6] define them as a tool for the formation of a dynamic information space. In

turn, SNSs provide actors with the means of representing their identity in the virtual space and the tools for creating different types of relationships with other actors (friends, followers, members of virtual communities, etc.). Among the basic SNSs functions, the following publications are highlighted [6]: management of the identification of actors to meet the needs for referring to a selected category of users and setting access rights to the profile; search of experts by means of proactive recommendation of relevant SNSs actors based on the given criteria - surname, interests, sphere of activity, etc.; contact management, which involves the functionality of interaction with a certain set of actors, in particular limiting access to the profile, designating actors in posts and content of different types; awareness of the actors' activity in SNSs includes tracking content publications, events in the lives of actors, events, participation in virtual communities; exchange of content between actors in SNSs with the use of direct and indirect means. While the direct exchange, there is a communication with the addressing of the content to the specifically defined actor. Indirect exchange includes the publication of photo and video content, the creation of public events and postings.

It is known that structurally SNSs represent a network of crosspoints – actors, which are linked by relationships – connections. Considering the peculiarities of the processes of interaction between actors, it is appropriate to describe SNSs as a complex nonlinear dynamic system [7, 8]. In the case of attack to the SIS in SNSs, the interaction of actors goes into chaotic dynamics, it becomes unpredictable and uncontrolled not only in the virtual space, but also in the real life of a society [9, 10]. The publications [11-13] show that the effective direction of threats' counteraction to the SIS in SNSs is the use of synergistic management. The main point of such management is to spread the content of directed matter in the information space of SNSs, and as a result of this influence, the processes of self-organizing actors happen. As a result, the indicators of the actors' interaction in SNSs, in particular the demand for content of destructive matter, reach the desired values, and the virtual community moves to a stable predetermined state of the information security. However, such studies are aimed at the SIS operational counteraction of threats in the information space of SNSs under the dynamic confrontation conditions. The task of forming the structures of actors' virtual communities, that are resistant to destructive information influences in SNSs, remains unresolved. This approach will allow to reduce the cost of resources for stable monitoring of SNSs information space and counteraction of threats to the SIS.

The analysis of academic research in the direction of artificially managed synthesis of stable structures of virtual communities in SNSs has shown that this issue has not been studied sufficiently [14-16]. The explicit direction of research is inextricably linked with the use of the virtual community's startup approach in SNSs. It is established that to the basic conditions for a successful startup of the virtual community in SNSs, which can be considered sufficient, it is appropriate to refer the following [17, 18]: the correct community's preparation for promotion; maintaining a stable number of actors who enter the community for a specified period of time; obligatory retention of the 10% barrier of the carriers' ideas of the virtual community; timely placement of high-quality content; the choice of rational ways of distributing content about the community, etc. At the same time, the success of the startup depends on whether the

virtual community gains a sufficient number of actors, that is, such a critical mass, which will be sufficient for its further self-development. Therefore, this condition can be attributed to the category of necessary ones, compliance of which is obligatory for the startup of all virtual communities in SNSs.

Also, from the literature analysis on the study's topic [19-23] it has been established that the problem of the virtual community's startup in SNSs on the critical mass principle has not been worked out either theoretically or methodically until today. The vast majority of studies [7, 20-22], etc., focus on mastering the issues of developing, researching and analyzing the SNSs models. Also, in a number of scientific publications [3-6] and others, attention is focused on the study of issues related to the social and humanitarian role of SNSs in the life of civil society.

Thus, the task of increasing the information stability of virtual communities in SNSs to destructive information influence by combining the approaches of the virtual community's startup in SNSs and the synergistic management of interaction between actors is a burning strand of the research.

3 Materials and Methods

3.1 Virtual Communities as Complex Dynamic Systems

Virtual communities in SNSs represent an association of actors that interact with each other to implement interpersonal and group communication in the information space [25]. As a result of such interaction, virtual community actors in SNSs create their own informational content. In turn, structurally, virtual communities in SNSs consist of a large number of actors and is a complex dynamic system with vertical and horizontal links between them. Therefore, in Fig. [1] we demonstrate the virtual community in SNSs as an unoriented graph.

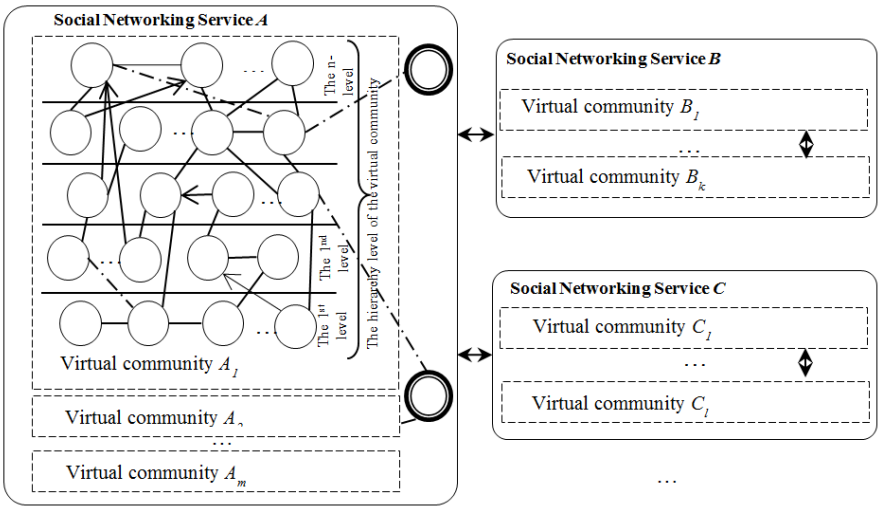


Fig. 1. The block diagram of the virtual community in SNSs

In fig. [1] actors in SNSs are marked with circles, and the interrelationships between them – with three types of lines: the solid line is used to represent stable relationships that ensure the cooperation of information interaction under the influence of external factors of the information space and remain unchanged (for example, friendship between actors); solid lines with arrows at the end point to flexible links between actors that are capable of responding instantly to changes in the information space parameters and are usually unidirectional (followers, etc.); weak links are marked by a dash-and-dot line and are characterized by significantly limited information interaction due to an inadequate level of common interests between actors.
Also, the figure shows two types of actors in SNSs. The first group of actors is represented by a solid circle – they are part of the virtual communities and interact with other actors in them; the second group is marked by a dual circle – these users do not belong to virtual communities, but they can monitor their activity. As a result of the attack to the SIS in SNSs, the interaction of actors becomes unregulated and uncontrolled, which leads to the emergence of chaotic dynamics. Signs of chaotic dynamics of actors' interaction processes in SNSs are:

- appearance of high sensitivity to the initial conditions that characterize the information space;
- fractal motion marks of the depicting point in the system's phase space;
- the increasing complexity of establishing links between actors and virtual communities as a result of changing some of the parameters of the SNSs information space;
- the transitional chaotic reactions of actors and virtual communities to distributed content, non-periodic bursting of the content publication of destructive matter, or the irregularity of the distribution of such content from the moment it is thrown into the information space.

Therefore, the functioning peculiarities of virtual communities' actors in SNSs in the conditions of carrying out destructive information influence cause a conceptual problem, the solution of which is aimed at reducing the level of information entropy in the system in order to stabilize the actors' public opinion, increase their level of critical perception of misinformation and, finally, regularization of interconnections between members of the community and the decisions they make.

3.2 Information Stability of Virtual Communities in SNSs

It is known that in the broad sense, the immunity of social communities is the ability to use their own resources to respond, to counteract and to continue functioning under the influence of negative factors [25]. The publications [7, 9, 11, 12] have proved that as a result of the attack to the SIS in SNSs, not only the promotion of content of destructive matter in the information space happens, but also the change in the relationship between actors and, as a consequence, structures of virtual communities.
Therefore, under *the information stability of the virtual community in SNSs*, it is suggested to understand its ability to respond and to recover from the impact of threats to information security, to adapt to changes in the information space and to realize their

purpose of functioning. The category under consideration differs from the information security concept of the virtual community considering the requirement for its sustainable development in the SNSs environment. Under the conditions of information confrontation with the use of SNSs, intruders use innovative technologies of information influence on actors and, due to technological advantages and element of surprise, can successfully achieve their objectives. At the same time, assisting the information security of virtual communities involves activities aimed at excluding the possibility of implementing external and internal threats in the SNSs information space [9]. Consequently, the achievement of the information stability of the virtual community in SNSs provides preliminary readiness, adequate response and successful recovery to the given state of the virtual community's information security after the SNSs threat.
Factors that affect the information stability of virtual communities in SNSs are presented in Fig. [2].

Fig. 2. Components of the information stability of the virtual community

The achievement of the SIS in SNSs is possible as a result of the realization of an effective state policy in the information sphere in accordance with the current legislation, the use of a complex measures aimed at meeting the contemporary challenges in the information space and the means of controlling them. The guarantee of the SIS in SNSs is primarily the responsibility of the relevant departments, which are determined by the current legislation of the certain state. In particular, the national interests of Ukraine in the information sphere, the threats to their implementation, the directions and priorities of state policy in the information sphere are determined by the Doctrine of Information Security [26].

Social norms in SNSs are represented by a set of generally accepted rules, standards, relations between actors that provide the sequences of the virtual community, the stability of the processes of interaction between actors in the context of attacking the SIS [27]. Social sanctions in SNSs are a set of punishments in the legal field of the state and the SNSs environment, which are used in the case of detecting deviations from the generally accepted norms of interaction between actors and virtual communities in order to meet the respected community standards in the information space of SNSs [27]. According to the work of Michael Scriven & Richard Paul [28], critical thinking of actors in SNSs is an intellectual process for the active reflection, application, analysis, synthesis and / or evaluation of content collected, or generated through observation, experience, reflection, reasoning or interaction with other actors, which prompts actions in the information space of SNSs.

3.3 The method of forming the informationally stable virtual communities

We envisage the formation of a stable virtual community using an approach based on the virtual communities' startup in SNSs. Considering the results of recent scientific studies [3-7] and experimental using [16, 22, 23], as well as the basic notions of nuclear physics, we give the following definitions of the critical mass of the virtual community in SNSs and its start-up:

- the critical mass M of the virtual community $c \in C$ in SNSs $g \in G$ is the minimum number of actors $a_{\min} \in A$ that are consuming and generating new content $k \in K$, which provides the activation of the viral (virus) loop v and self-development e of the virtual community;
- the virtual community startup in SNSs is a newly created virtual community $c \in C$ in SNSs $g \in G$, which twists under severe resource limitations $o_{\min} \in O$;
- viral loop v means the speed of content distribution between actors $a \in A$ of the virtual community $c \in C$ in SNSs $g \in G$;
- the critical state of the virtual community is the steady state of the virtual community $c \in C$ in SNSs $g \in G$, in which the number of actors $a_{const} \in A$ does not change in time $t \in T$;
- criticality means the conditions under which the virtual community $c \in C$ in SNSs $g \in G$ supports the mechanism of self-development e.

Taking into account the given definitions it can be confirmed that the problem of the virtual communities' startup in SNSs occurs when there is a need for rapid activation of the loop, which will ensure the self-development of the community under the conditions of severe resource limitations. But in practice, the solution of this problem involves solving the contradiction, which is to meet the needs of adjustment the high requirements that are put forward to the pace of the loop activation of the newly created virtual community with the involvement of a minimum number of actors, to the severe resource limitations that are set. So that, solving the discovered contradiction is suggested on the basis of the critical mass principle.

Since today there is no common approach for determining the critical mass for the startup of virtual communities in SNSs, at a first approximation the principle of critical mass in the formalized form can be described as following

$$\left\langle \min\left(M\right): a \geq a_{\min}, o \geq o_{\min} \right\rangle, \quad (1)$$

where $a_{\min}$ means the minimum number of actors required to provide a successful startup of the virtual community c in SNSs g, $a_{\min} \in A$, $c \in C$, $g \in G$; $o_{\min}$ describes the minimum cost of resources that is enough for a successful startup of the virtual community c in the social network g, $o_{\min} \in O$.

In the direct formulation, the task of determining the critical mass of the virtual community (1) is incorrect [29]. We regularize the principle (1). To do this, we use the metric of self-similarity – the Hurst index [30, 31]. Unlike the well-known metrics of self-similarity, the Hurst index will provide not only the trendsetting in the sequence of filling the virtual community with new actors, but also establish the nature of the startup. In such a way, the value of the Hurst index H is going indirectly to answer the question whether the virtual community of critical mass $\min\left(M\right)$ has reached a minimum number of actors $a_{\min}$ and dedicated resources $o_{\min}$ (1) or not, that is $\min\left(M\right) = H$. In Table [1], qualitative signs of the startup are defined by the quantitative values of the Hurst index.

Table 1. The balance between the critical mass of the virtual community and the values of the Hurst index while evaluating the quality of the virtual community startup

Resource assigned to a startup, $o_{\min}$, days	Category of startup quality on the critical mass principle $\min\left(M\right)$, depending on the change in the values of the Hurst index, H		
	unsuccessful	accidental	successful
15	0–0.330	0.331–0.668	0.669–1
20	0–0.337	0.338–0.662	0.663–1
25	0–0.342	0.343–0.657	0.658–1
30	0–0.347	0.348–0.652	0.653–1
35	0–0.351	0.352–0.647	0.648–1
40	0–0.354	0.355–0.645	0.646–1
45	0–0.356	0.357–0.643	0.644–1
50	0–0.359	0.360–0.639	0.640–1
55	0–0.362	0.363–0.637	0.638–1
60	0–0.364	0.365–0.634	0.635–1
65	0–0.366	0.367–0.633	0.634–1
70	0–0.367	0.368–0.630	0.631–1
75	0–0.368	0.369–0.629	0.630–1
80	0–0.371	0.372–0.628	0.629–1
85	0–0.372	0.373–0.627	0.628–1
90	0–0.373	0.374–0.626	0.627–1
95	0–0.374	0.375–0.624	0.625–1
100	0–0.376	0.377–0.623	0.624–1

The calculation of Hurst indexes, which will determine the quality category of the virtual community startup in the social network, is performed according to the expression

$$H = \frac{\lg(R/S)}{\lg(m \cdot \pi/2)}, \tag{2}$$

where H is the Hurst index; S means average deviation of a number of observations; R is the dispersion of accumulated deviation; m is the number of observations.
Consequently, adherence to the critical mass principle provides the stable development of the virtual communities' dynamics, which in the future excludes the reduction of the number of their actors, provides the stability of interaction relations between them, the ability to perform functions of social control. Thus, the startup of virtual communities in SNSs based on the critical mass principle serves as a guarantee of increasing their level of information stability.
For a case when the virtual community startup in SNSs according to the data in tab. 1 is characterized by qualitative indicators "unsuccessful" or "accidental", it is not capable of independent functioning and development. Achievement of a given level of information stability by such virtual community is possible only with the constant hidden information influence on the actors in SNSs. Such security actions require the use of significant resources – financial, human and technical, etc. Therefore, we analyze the process of forming a virtual community of actors, which will be capable of stable self-development by activating the loop in SNSs using synergistic management [9].
Considering the high speed of growing the number of actors and virtual communities in SNSs, the origin of evolutionary processes within the virtual communities, the intensity of information exchange between SNSs and the external environment of its functioning – the national and world information spaces, we use the model of microbiological system for the description of the actors' interaction in SNSs [32]. At the same time, the publication of the content of given matter is carried out by members of the virtual community team in SNSs, acting as its administrators.
Therefore, we formalize the processes of interaction between actors of the virtual community in SNSs in the form of the Mono model [13, 32, 33], which is a system of ordinary differential equations

$$\begin{cases} \dfrac{dx(t)}{dt} = \mu(Q)x - Dx, \\ \dfrac{dQ(t)}{dt} = DQ_0 - \alpha\mu(Q)x - DQ; \end{cases} \tag{3}$$

where $x(t)$ stands the number of actors in the created virtual community; $Q(t)$ describes a part of team members' publications in the virtual community; Q_0 means a part of new publications on a given topic in the virtual community, published by team members; D indicates the speed of new members' appearing of the virtual communi-

ty in the absence of artificial influence on actors; α^{-1} indicates the coefficient, which specifies a part of publications on a given topic, which has influenced the formation of public opinion of the virtual community actors; $\mu(Q)x$ means the increase in the number of actors in the virtual community due to the impact of published content by team members, $\mu(Q)=\frac{\mu_z Q}{k_z+q}$; $-Dx$ stands the reducing the number of virtual community actors; $-\alpha\mu(Q)x$ stands the number of publications that has influenced the formation of public opinion of virtual community actors; DQ_0 describes the intensity of publications that has caused interest in actors of SNSs and has encouraged them to become participants in the virtual community; $-DQ$ means the intensity of publications that hasn't caused interest in actors of SNSs and hasn't encouraged them to become participants in the virtual community.

Limitation 1. The growth rate of a virtual community's participants depends only on the part of team members' publications in the virtual community.

Limitation 2. The participants' publications of a virtual community team are distinguished by content, form of material feed, content type, but are joined together by a common narrative, which must be get across to actors in direct or latent form to influence their public opinion.

We perform the synthesis of such synergetic management $u(t)$, which will provide the formation of a virtual community of actors in SNSs, capable of further sustainable functioning with the aim of spreading and promoting a strategic narrative aimed at counteracting destructive information influence. Then the system of differential equations (3) will take the form where the part of new publications on a given topic in the virtual community, published by the team members Q_0 will be specified by the controlling action $u(t)$

$$\begin{cases} \frac{dx(t)}{dt}=\mu(Q)x-Dx, \\ \frac{dQ(t)}{dt}=Du(t)-\alpha\mu(Q)x-DQ. \end{cases} \tag{4}$$

Artificially controlled self-organization of actors in SNSs in the virtual community will be achieved through the entry of a dynamic invariant into the system (3). The chosen dynamic invariant should consider the peculiarities of the processes of actors' social communication in SNSs. From the studies [8, 34] it is known that the increase in the number of actors of the virtual community at a certain stage of its development is slowed down and asymptotically reaches the boundary level. It is rational to formalize this phenomenon in the form of a differential equation of logistic type

$$\frac{dx(t)}{dt}=\beta x_{\sup}x\left(1-\frac{x}{x_{\sup}}\right), \tag{5}$$

where β stands the parameter that determines the desired rate of increasing the number of the virtual community actors; $x_{\sup}$ indicates the limited number of participants in the virtual community at the stage of its development.
The use of the model (5) to describe the processes of creating a virtual community in SNSs provides the visibility of their demonstration, in comparison with other models of logistic type, presented in publications [11-13].
Consequently, in accordance with the concept of synergistic management of the actors' interaction in SNSs, suggested in [11], and taking into account (5), the parameter of the system's order is its attractor, to which all the phase trajectories of the controlled system (4) will follow, takes this form

$$\psi(t) = \mu(Q) - \beta x_{\sup}\left(1 - \frac{x}{x_{\sup}}\right) - D. \tag{6}$$

The physical content of the function $\psi(t)$ is to reduce the need for the content of the specified matter to be provided by the members of the virtual community of SNSs $\mu(Q)$ by increasing the number of the virtual community members to the critical level [35] in accordance with the expression $\beta x_{\sup}\left(1 - \frac{x}{x_{\sup}}\right)$ and the speed of the new members' appearing in the virtual community D.
According to [11, 13] expression (6) must satisfy the functional equation

$$T\frac{d\psi(t)}{dt} + \psi(t) = 0, \tag{7}$$

where stands the time during which a synergically controlled virtual community will have transient processes to a given state of the SIS in SNSs.
The substitution of the attractor's model (6) in the differential equation (7), considering the system (4), allows us to specify the analytical form of the model of synergetic management

$$Du(t) = \alpha x\mu(Q) + DQ - \frac{(k_z + Q)^2}{\mu_z Q}\left(\beta x\mu(Q) + Dx + \right.$$

$$\left. + \frac{1}{T}\left(\mu(Q) - - \beta x_{\sup}\left(1 - \frac{x}{x_{\sup}}\right) - D\right)\right. \tag{8}$$

In order to achieve a stable state by the current virtual community in SNSs, we will perform a study of the system of differential equations (4) on the stability using the Lyapunov's function method [36]. For the number of actors in the virtual community in SNSs $0 < x_{\psi} < 1$ the derivative from the Lyapunov's function $V' < 0$, if $x_{\sup} > 1$

where $\beta \le D$, when $\beta > 0$ and $D > 0$. In the case $x_{sup} = 1$ of system (4) is stable where $\beta > 0$ and $D < 0$ or $\beta < 0$ and $D > 0$. In the same way, other conditions of the system's stability (4) are specified.

As a result of the synergistic management's influence (7), the processes of actors' self-organization will be started in SNSs, and after a while the system will reach the point of a burst of synergistic effect [11], in which the virtual community will move to a steady state. The coordinates of the splash point of the synergistic effect acquire the following values

$$x_1 = x_{sup} + D\left(x_{sup} - \frac{1}{\beta}\right), \tag{9}$$

$$Q_1 = \frac{k_z}{\mu_z} \frac{\beta x_{sup}\left(1 - \frac{x_1}{x_{sup}}\right) + D}{1 - \frac{1}{\mu_z}\left(\beta x_{sup}\left(1 - \frac{x_1}{x_{sup}}\right) + D\right)}.$$

In Fig. [3] a BPMN diagram of the worked-out method for improving the information stability of virtual communities in the Aris environment is presented, and its main stages are specified.

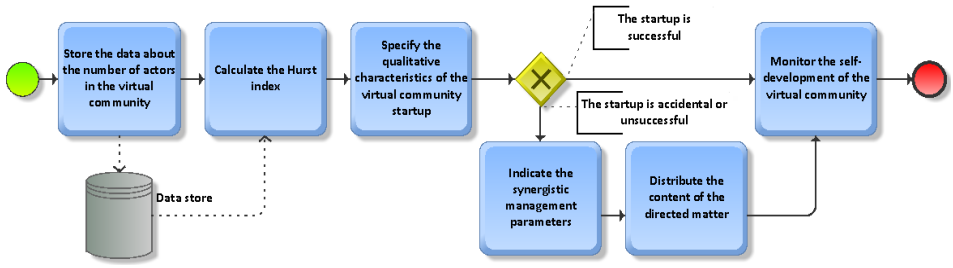


Fig. 3. BPMN-chart of the worked-out method

4 Experiments

We will undertake an experimental study of the worked-out method for increasing the information stability of actors in SNSs on the example of virtual communities c_1 and c_2 in SNSs Facebook. The names of virtual communities c_1 and c_2 are not disclosed due to their commercial secrecy.

As inputs for estimating the critical mass for the startup of virtual communities c_1 and c_2 in SNSs Facebook, the experimental data received in 2014 have been used and presented in Table [2].

Table 2. Input data from the startup of virtual communities c_1 and c_2 in SNSs *Facebook*

Day	Date	Virtual community					
		c_1			c_2		
		actor's number			actor's number		
		increase	decrease	total	increase	decrease	total
1	08.03.2014	8	0	8	15	0	15
2	09.03.2014	5	0	13	41	0	56
3	10.03.2014	21	0	34	33	0	89
4	11.03.2014	38	0	72	106	0	195
5	12.03.2014	43	0	115	39	0	234
6	13.03.2014	32	0	147	46	0	280
7	14.03.2014	3	0	150	27	0	307
8	15.03.2014	2	0	152	47	0	354
9	16.03.2014	42	0	194	2	0	356
10	17.03.2014	63	0	257	19	0	375
11	18.03.2014	57	0	314	10	0	385
12	19.03.2014	84	0	398	8	0	393
13	20.03.2014	48	0	446	35	0	428
14	21.03.2014	90	0	536	13	0	441
15	22.03.2014	21	0	557	42	0	483
16	23.03.2014	23	0	580	19	0	502
17	24.03.2014	3	0	583	15	0	517
18	25.03.2014	2	0	585	154	0	671
19	26.03.2014	20	0	605	50	0	721
20	27.03.2014	5	0	610	61	0	782
21	28.03.2014	23	0	633	32	0	814
22	29.03.2014	0	0	633	4	0	818
23	30.03.2014	0	0	633	179	0	997
24	31.03.2014	82	0	715	86	0	1083
25	01.04.2014	9	0	724	49	0	1132
26	02.04.2014	26	0	750	60	0	1192
27	03.04.2014	16	0	766	17	0	1209
28	04.04.2014	46	0	812	65	0	1274

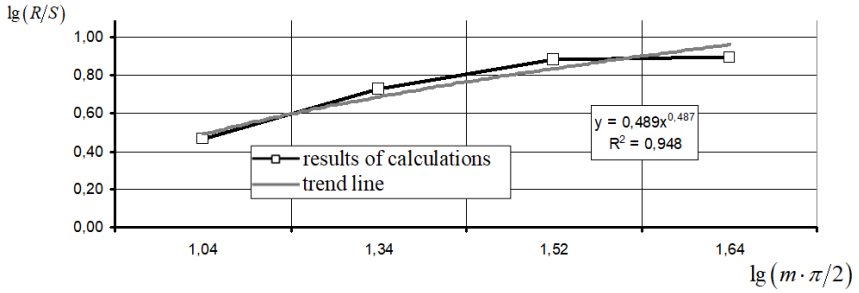
Promotion terms of virtual communities' actors c_1 and c_2 are presented in Table [3].

Table 3. Terms of the virtual communities' startup c_1 and c_2

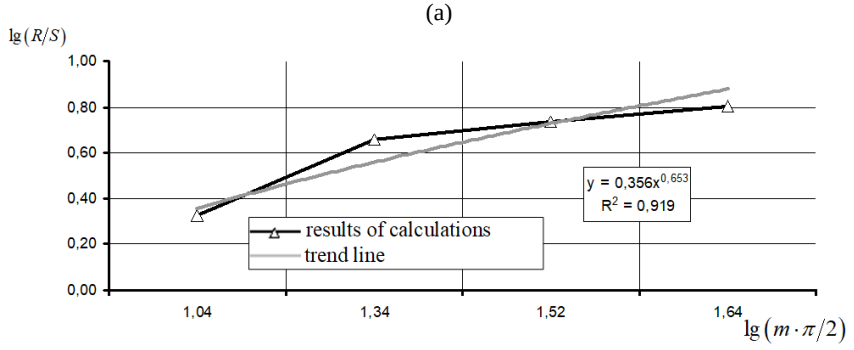
Sufficient conditions for promotion of the virtual community	Virtual community	
	c_1	c_2
The correct preparation of the virtual community for promotion	+	+
Keeping a stable number of actors entering the virtual community for a specific period of time	+	+
Obligatory keeping of the 10% barrier to the idea of a virtual community	–	+
Timely publication of high-quality content	–	+
Choosing rational ways to spread information about the virtual community	+	+

Calculation of the corresponding metrics of self-similarity (2) for virtual communities c_1 and c_2 has been carried out according to a well-known method [30, 31]. Results of *R/S*-analysis of the virtual communities' functioning is presented in Fig. [4] (a), (b). The analysis of the obtained results allow us to draw the following conclusions:

1. the values of Hurst indexes for virtual communities c_1 and c_2 are $H_{C_1} = 0.487$ and $H_{C_2} = 0.653$ accordingly. In Fig. [4] the corresponding values of the indexes H_{C_1} and H_{C_2} are indexes of degree in the equations of approximation;
2. comparison of the obtained results with the data of Table [1] shows that for resource $o_{\min} = 28$ days that is dedicated to the creation of virtual communities, virtual community c_1 has no critical mass $\min(M)$. The Hurst index for this community characterizes the process of filling it with new actors, as a process of random nature.



(a)



(b)

Fig. 4. Results of R/S- analysis: the virtual community c_1 (a); the virtual community c_2 (b)

In the second case - for a virtual community c_2, the obtained results allow to approve that the startup is successfully hold. The process of filling the virtual community c_2 with an accuracy of 99.73% is persistent, that is, it has signs of a trend. Thus, the critical mass $\min(M)$ for a given virtual community for certain condi-

tions will reach $a_{\min} = 1274$ actors. As a result of the successful creation of the virtual community c_2 in SNSs Facebook on the critical mass principle $\min(M)$ (1), (2) the activation of the virtual loop v has been provided and the mechanism of self-development e has been launched. The adduced conclusion is confirmed by the practice, as of 11/18/2014 as a result of the launch of the virtual community's c_2 self-development mechanism e on the principle of critical mass $\min(M)$, the number of actors in it is 2211. As a result, this virtual community becomes resistant to destructive information influence, is able to perceive such content critically, uses in its activity the mechanisms of social control and social norms to neutralize the threats to the SIS in SNSs. Also, an additional factor that increases the information stability of the virtual community is the state actors' actions to provide SIS.

Consequently, to manage the processes of creating a virtual community c_1, in which the self-development mechanism has not been launched due to the use of the critical mass principle, we apply synthetic synergistic management (8). In this case, the parameters of a controlled system of differential equations (4) acquire the following values $\mu_z = 0,5$, $k_z = 0,5$, $\alpha = 0,3$. The speed of the appearing of the virtual community's new members in the absence of artificial influence, we define as the coefficient of linear regression equation for a number of data of the total number of actors in Table [2], which comes to the fore $D = 0,031 \cdot 10^3$ actors / day. The duration of transitions in a synergetically controlled virtual community $T = 1$ day. Initial number of actors in the virtual community $x(0) = 0,008 \cdot 10^3$, a part of team members' publications in the virtual community $Q(0) = 2\%$. Let the desirable growth rate in the number of virtual community actors figures up to $\beta = 0,05 \cdot 10^3$ actors per day, and the limited number of actors in the community at the stage of its development is – $x_{\sup} = 5 \cdot 10^3$ actors. Then, the modeled results of the synergistic impact on the virtual community will look like as in Fig. [5], and a change in the part of publications of team members in a controlled virtual community – in Fig. [6].

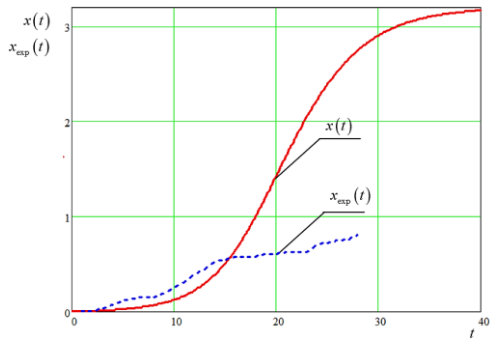


Fig. 5. The number of virtual communities in SNSs, 10^3 actors: a synergetically controlled process of formation $x(t)$; an uncontrolled process of formation $x_{\exp}(t)$

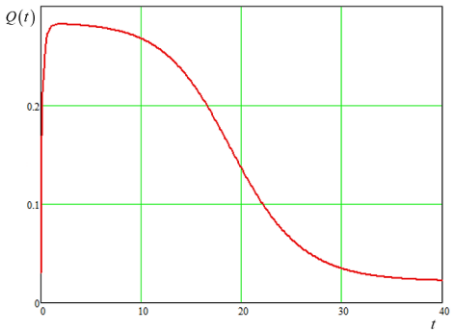


Fig. 6. Dynamics of the part of team members' publications in a controlled virtual community

The data analysis in Fig. [4] shows that in the case of a synergically controlled information impact on virtual community actors in SNSs, their number over the period of $t = 40$ days increases to $3{,}17 \cdot 10^3$. In this case, in the absence of such influence in $t = 28$ days after the experimental data, the number of actors will equal $0{,}812 \cdot 10^3$, and with its use – $2{,}843 \cdot 10^3$. It should be noted that the synergistically controlled information impact on the actors of the investigated virtual community in the early stages $t \in [0;15]$ provides a lower rate of growth in the number of participants and is a bit inert. However, at the next stages, $t \in [16;40]$ the process of attracting new actors is much more intense. At the same time, the part of the team members' publications in the virtual community in SNSs $Q(t)$ on the first day is 28% and gradually decreases to 2.2% in $t = 40$ days. The virtual community that is being synthesized will independently distribute multimedia content with a specified narrative, which will counteract the threats to the SIS in SNSs.

Consequently, the effectiveness of synergetically controlled information influence on virtual community actors in SNSs increases in 3,5 times in comparison with the natural processes of their creation, and the virtual community formed in such a way is capable of further self-development through self-organization processes and informationally sustainable against the impact of IS threats.

5 Conclusions

For the first time, to provide the SIS in SNSs, a method for increasing the information stability of virtual communities is worked out, based on a combination of the critical mass principle and the principle of synergistic management of the actors' interaction. At the same time, the information stability of the virtual community in SNSs is reduced to the ability of responding and recovering after the impact of threats to information security, adapting to changes in the information space and realizing their purpose of functioning. It is proved that adherence to the critical mass principle provides stable development of the virtual communities' dynamics and their information stabil-

ity, which in the future excludes the reduction in the number of their actors and provides further self-development. For virtual communities that are characterized by unsatisfactory qualitative indexes of the startup, the self-organization of actors in SNSs is due to the influence of synergistic management. In such a virtual community there are coherent collective processes and the directed self-organization of the community and the parameters of interaction processes between actors. Such a virtual community is informationally resistant to the impact of threats to the SIS in the information space of SNSs. In the future it is planned to investigate the influence of the promotion conditions of the virtual community in SNSs to its critical mass.

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