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Research Article

Competitive Interaction Model for Online Social Networks' Users' Data Forwarding at a Subnet

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Social Networks Ecosystem is evolving faster and Social Networks users' intensive activities are affecting significantly the network traffic. Generated data from different sending and receiving hosts have to be handled by network active nodes and links. In this paper, we propose to study the interaction between two types of network active hosts by using a Lotka-Volterra competitive system that considers the subnet limiting supply. We applied our proposed model to two kinds of Online Social Networks' (OSNs') users characterized by the intensity of their activities from the generated data perspective. We assumed and proved that the impact of competition is flexible and subject to forwarding protocol and subnet allocated resources. By taking the competition case in the analysis of the differential equations, we show that when competition exists, one stable equilibrium point can be found if certain conditions are respected. Numerical results confirm our theoretical analysis and show that instead of treating equally at the subnet level all data from active hosts, adopting a routing protocol that takes into account the nature of data and the forwarding time is necessary for improving the overall performance of the network.

1. Introduction

In today's highly connected society, Online Social Networks (OSNs) are evolving as their users are growing faster. Their demands consume more network resources in terms of traffic. Understanding the Social Networks Ecosystem evolution dynamic and the complexity of their interactions with the surrounding environment has attracted many system scientists and researchers interests. Traffic analysis has shown heavy traffic on the Internet and predicted OSNs continuous growth as Internet has become ubiquitous [1–4]. To meet customers' satisfaction, network systems have to evolve and must provide high quality Internet services at any time. But, we know that Internet is a packet-based network. The transmission of information is done in "discrete packets" [5, 6]. The path followed by a packet when traveling the network is determined by the "routing algorithm." This algorithm is responsible for minimizing data packets delivery time and maximizing the throughput. Internet network topology and statistical properties play important role in this job. Different distributions processes rule the whole delivery. Internet network has also been proved to be highly self-similar due to its tendency to burst data and to forward them by packets of different size [7, 8]. If the network is busy servicing a certain amount of data packets at the subnet level, arriving new data must queue waiting in the line with relative length, depending on the size of the buffer, the topology of the network, and other parameters. Thus, factors such as service time, latency, and network allocated resources play key roles in guaranteeing QoS and optimizing resources [9]. From the network point of view, all packets are equal and have to be handled. The nature of their sending or receiving hosts' activity is hidden in data treatment process. The only thing that matters for the subnet is the delivery efficiency. For network managers and for Internet service providers, understanding the populations of OSNs and the relations between different species and ecosystems interactions can help to orient future actions or decisions. Analyzing network behavior, planning network traffic, and monitoring in order to dispatch network resources consumers and optimize routing protocol are some important parts of the network administration and Internet resources management job [10–12].

If we take a close look at the populations interacting in the SNs, they can be represented by sending and receiving hosts. Their interactions can be modeled as in the ecological competition system. In this paper, we deal with OSNs "intensive users" as predators because they create more traffic on the network. We consider all other users whose behaviors do not generate significant traffic as preys. Lotka-Volterra model of interspecific and intraspecific competition is one of the well-known and powerful models used for formalizing influences and interactions [13, 14]. We know that an active user can randomly change his status into one of the two kinds mentioned above or simply get off the line. This dynamic makes their impact on each other challenging to model. We only consider their interactions dynamic at the set of active nodes and links represented by the data they generate when the corresponding packets enter the subnet and travel through the network.

Significant progress has been made in understanding the dynamic of interactive populations and the related literature about the classic predator-prey system and others is rich and widely spread [15–21].

We analyze the differential equations of the model to find the stability points and the conditions parameters have to respect to make the two species coexist and compete. Then we tested the predictability of the model when population's densities vary over time. In the numerical simulations interesting results were found about the sensitivity of the two species' growth rate in the case of limited network supply identified by the carrying capacity in the model under a routing protocol that treats equally all data packets [22–27].

2. Related Work

In this section, we present relevant works that inspire our study and have direct and indirect relation with our approach.

Early work realized by Jeffrey Mogul and John Pastel about the practice called "subnetting" has focused on showing the importance of dividing the network into smaller networks or segments to improve the allocation of address space in IPV4 architecture using CIDR (Classless Inter-Domain Routing) [28]. Complementary works have been done for IPV6 by many authors like T. Narthen et al., Ralph Becker, and so forth.

In many publications and reports, Cisco engineers have inspired our analysis and work by providing comprehensive guides on how to configure and use a subnet to improve data forwarding and network overall performance, particularly, in the case where a single subnet is considered. Useful techniques on how Ethernet Host Subnet, IB host Subnet, and Remote Subnet work in data packets forwarding process can be found in "Cisco SFS Infiniband Software Configuration Guide."

In their inspiring recent work about packets routing protocol, Haramaty et al. show how data packets travel the network through different subnets and how they are routed among nodes using layer-3 addresses that are uniquely assigned to each node [29]. This work provides solution to manually manage packets forwarding through many segments of the network that will be used to forward a certain amount of packets.

As Internet is decentralized in nature and is comprised of multiple administrative domains, early work by Sally Floyd and Van Jacobson has provided evidence on the importance of taking decision on network usage at links or nodes level to guarantee that capacity of the network will respond and behave under heavy traffic load.

Unfortunately only few studies have been made to analyze the network traffic impact of OSNs' users' activities. We can cite C. Wilson et al., Schneider and al., and Long Jin and al. who devoted their studies to understanding OSNs users' behavior and especially what happens within an OSN when users interact with it [10]. Their works focused on network data traffic generated by released new features, for example. Data traffic has been extracted from a passively monitored network to analyze the impact of OSNs' users' activities on the network behavior.

Nevertheless, all these studies explored different aspects of data forwarding at the network nodes and links and did not consider the interaction between different packets that travel the segment of the network at a certain time when the network is busy. There are many factors that have to be taken into account when analyzing the origin of a possible poor performance of the network. Our approach explores the possible packets competition for being forwarded at the subnet level.

3. Model

We describe, in this section, the basics of subnet data packets handling and forwarding system and establish a competitive Lotka-Volterra type model based on this network segment particular characteristics.

3.1. System Description. When Social Networks' users are interacting within the network, their behavior reflects directly the nature of their activity. The data they generate travel the network starting from the device they are using denoted by the sending node to the destination server identified by the receiving node. Between the two nodes, according to the topology of the network they are connected to, their data will be handled by a subnet which can be considered as a segment of the network. A subnet is usually composed of a certain number of nodes and a fixed or variable number of links. In the model, as data generated by users are proportional to the intensity of their activities, we define then users' activities as a growth factor. The nature of users' activities on the SN network defines also the amount of data packets they generate. For analysis purpose, we choose U_1 and U_2, respectively, to represent the amount of data traveling the subnet from the two kinds of users. The first user is the weaker one because we put in this group all users whose behaviors are not driving a lot of data traffic on the network. The second kind of users corresponds to the stronger species. We put in this group all users with heavy data traffic behaviors. Any of the two kinds of users have the freedom to switch his status by stopping what he is doing online or just moving to another type of activity. This phenomenon can be considered as the decay factor of the two populations.

Data packets have a limited time to spend on the segment of the network. Their life cycle can be short or long depending on the characteristics of the network or the subnet. The nature of users' activity has also a significant impact on that service time. In fact, we assume that the second species generates data at higher speed according to the nature of their activities. Therefore, data packets from the first or the second species have relative life cycle. The size of the buffer, the quality of active links, nodes supply, subnet supply, and the routing protocol, all have, in addition, a direct impact on data packets life cycle. In our analysis, we use N to represent all the mentioned parameters that interfere on the life cycle and consider it as the carrying capacity of the environment. If we consider that all data packets have the same characteristics in terms of size, for example, then we have to admit the similarity of the impact of N on the studied populations.

Let us suppose a user is using Social Network at time t; then the data his activity generates arrive at the subnet and are taken in packet form. As mentioned above, $U(t)$ represents his data packets number variation in time interval $[t-1, t]$. Let us consider $U(t)$ growth over time as a logistic pattern in the case where only one species exists and set

$$\dot{U}(t) = cU(t)\left(1 - \frac{U(t)}{N}\right). \tag{1}$$

Here c is a constant denoting the growth factor impact on the user's packets that are traveling the subnet. The total number of packets, up to time t in the subnet, is represented by U. When packet number U reaches N, its value will decrease. Meanwhile, the growth rate of user's packets will be influenced by the decay factor d. Incorporating this factor in (1), we have

$$\dot{U}(t) = cU(t)\left(1 - \frac{U(t)}{N}\right) - dU(t). \tag{2}$$

The main features of (2) can be described as follows.

(i) $\dot{U}(t) = 0$ or packets number reaches its maximum N.

(ii) When $0 < U(t) < N$, then arriving packets will enter the subnet. The growth rate of the considered populations will obey the relation (2).

This analysis proves that the growth rate of packets in the subnet is function of the growth factor and the decay factor depending on the subnet supply. We discuss the situation where data packets are originated from different type of users in the next section.

3.2. Lotka-Volterra Competition Model. Data packets handling and forwarding through the network is a complex process. At the subnet nodes or links, packets travel different segments. Their travel times and the probability that they arrive at the destination node are relative and submitted to several factors such as the routing protocol. If we assume network subnet to be loyal and to service all packets without special treatment, then, because of the limitation in terms of network supply, data packets have to compete in order to get served first. This phenomenon can be assimilated to the competition interaction between different species formalized by the classic Lotka-Volterra competition model. Hence, it is logical to consider that competition happens when users are interacting intensively and the network is busy servicing them.

In this section, we study the common case of competition between two types of users identified by the nature of their activity on the Social Network. We assume that, on the same window time, data packets will compete regardless of their source node and the network will choose to give them access to the resources in function of their destination or receiving node. In addition to the intercompetition, packets will also face the inner competition, since we consider that all packets are treated equally through the network. We put all Social Networks' users into two groups. For simplicity purpose, we assume all packets have the same size and their arrival rate is a constant. Let this competition process be governed by the following rules.

(i) The studied two types of users are represented in the system by the data packets they generate when they behave through the platform they are using.

(ii) All data packets traveling the subnet are identical in terms of size and their arrival rate is considered to be the same without variation with time.

(iii) Data packets from the two species have relative stable natural growth coefficient α and β, respectively, and the same relative stable decay factor θ. All three of them are positive real numbers.

(iv) All data packets present in the subnet are submitted to the same carrying capacity N explained by the subnet supply or the number of packets the network can handle or forward during the window time. $N > 0$.

(v) The two species will compete with one another. This action will have a positive action on the second species considered as the predator and a negative influence on the first species considered here as the preys. These growing and decreasing factors are represented by p and q, respectively, positive and negative constants numbers. According to rules (iii), (iv), and (v), we have the following model:

$$\begin{aligned}\dot{U}_1 &= \alpha U_1\left(1 - \frac{U_1}{N} - pU_2\right) - \theta U_1,\\ \dot{U}_2 &= \beta U_2\left(1 - \frac{U_2}{N} + qU_1\right) - \theta U_2.\end{aligned} \tag{3}$$

Here $\dot{U}_1$ and $\dot{U}_2$ are the first derivative of the growth function representing the growth rate of each species over window time. α, β, N, p, and θ are positive constant parameters and q is a negative real number. Equation (3) is considered then as a competition system.

Let $U_2 = 0$ in the first equation of system (3); we get $\dot{U}_1 = \alpha U_1(1 - U_1/N) - \theta U_1$; it is clear that αU_1 is the natural growth of the first species in the absence of the predators. θU_1 is then the decay factor and then $\theta \in [0, 1]$. By similarity, this result holds for the second equation of system (3) when only species two is interacting with the network. Supported by rule (iv), we know that the carrying capacity of the subnet is limiting the

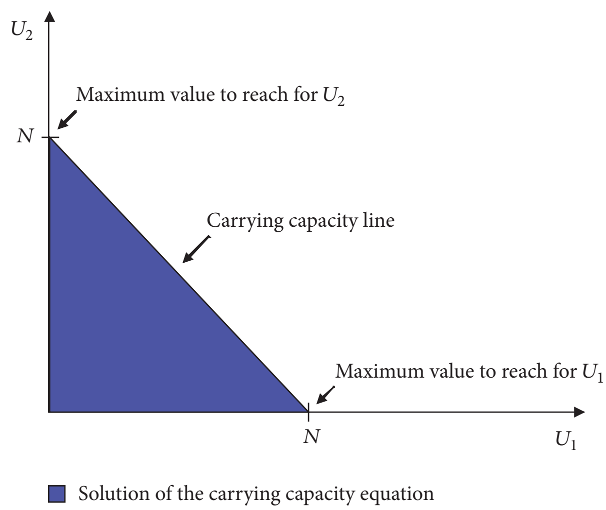


Figure 1: The carrying capacity line.

total amount of packets present in the segment of the network over time as shown in Figure 1.

The carrying capacity equation can be written as follows:

$$N = U_1(t) + U_2(t). \tag{4}$$

It can be seen that the subnet supply named carrying capacity line is boarding the solution space by keeping density of the population under it.

4. Model Analysis

In this section we discuss the dynamic of the Lotka-Volterra model by analyzing the position of the two isoclines and the global stability of the system.

4.1. Elementary Analysis. In int $\mathbb{R}_+^2$, the zero growth isoclines of U_1 and U_2 are as follows:

$$\begin{aligned} U_1 &= -NpU_2 + \frac{N}{\alpha}(\alpha-\theta), \\ U_2 &= \frac{N}{\beta}qU_1 + \frac{N}{\beta}(\beta-\theta). \end{aligned} \tag{5}$$

Three regions of the solution in int $\mathbb{R}_+^2$ are worth discussing as shown in Figures 2 and 3 indicated by the directions of the vectors fields.

Based on Figures 2 and 3, species one will always shrink in the space above its zero isoclines and $N(\alpha-\theta)/\alpha$ will always be attracting around abscises axis. Similarly, species two will always shrink in the space above its zero isoclines and $(\theta - \beta)/q$ will always attract around abscises axis.

It is obvious that system (3) admits four equilibrium points in the first quadrant $\mathbb{R}_+^2$ representing the solution of the differential equations in this part of the Euclidian space. Let P_0, P_1, P_2, and P_3 be the four points mentioned above. If we set

$$k_1 = 1 - \theta - \beta, \tag{6}$$

$$k_2 = 1 - \alpha + \beta, \tag{7}$$

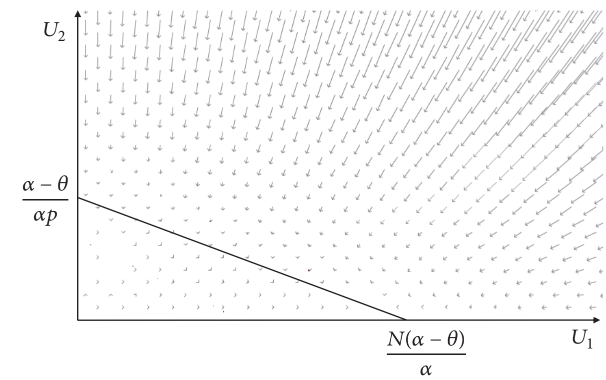


Figure 2: Direction fields of the x-isoclines.

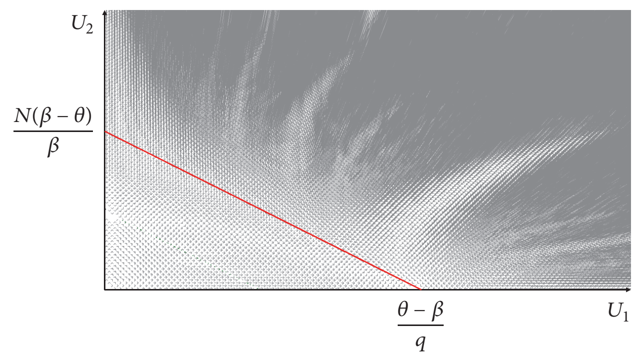


Figure 3: Direction fields of the y-isoclines.

$$k_3 = 1 + \theta - \beta, \tag{8}$$

$$k_4 = \alpha\beta\left(pqN^2 + 1\right) \tag{9}$$

as $\alpha, \beta > 0$, it is clear that $k_4 \neq 0$ as far as $pqN^2 \neq -1$; then we can write the coordinates of the four points as follows:

$$\begin{aligned} P_0 &= (0;0), \\ P_1 &= \left(-\frac{N}{\alpha}k_2;0\right), \\ P_2 &= \left(0;-\frac{N}{\beta}k_3\right), \\ P_3 &= \left(\frac{\alpha pN^2k_3 - \beta Nk_2}{k_4}, \frac{-\beta qN^2k_2 - \alpha Nk_3}{k_4}\right). \end{aligned} \tag{10}$$

4.2. Equilibrium Points. We study the stability conditions of the four equilibrium points of system (3) in this section in order to analyze the final result of competition between the two different SN users. Given the fixed points $(\overline{U}_1, \overline{U}_2)$, let the Jacobian matrix about this fixed point be

$$F_J(\overline{U}_1, \overline{U}_2) = \begin{pmatrix} A & B \\ C & D \end{pmatrix},$$
$$A = \alpha\left(p\overline{U}_2 - \frac{2}{N}\overline{U}_1\right) + \alpha - \theta,$$
$$B = -\frac{\alpha}{N}\overline{U}_1^2 + (\alpha - \theta)\overline{U}_1^2 - \alpha p\overline{U}_2, \quad (11)$$
$$C = -\frac{\beta}{N}\overline{U}_2^2 + (\beta q - \theta)\overline{U}_2 + \beta,$$
$$D = \beta\left(q\overline{U}_1 - \frac{2}{N}\overline{U}_2\right) + \beta - \theta.$$

It is admitted that if the eigenvalues of the Jacobian matrix about the fixed point lie inside the open unit disk $|\lambda| < 1$, then the point is locally asymptotically stable. If for one of them $|\lambda| > 1$, then the system is unstable at the considered point.

(i) For the equilibrium point $P_0 = (0; 0)$, we have

$$F_J(0,0) = \begin{pmatrix} \alpha - \theta & 0 \\ \beta & \beta - \theta \end{pmatrix}. \quad (12)$$

If $\lambda_1 = \alpha - \theta < 1$ and $\lambda_2 = \beta - \theta < 1$, then P_0 is a locally stable point of the system. P_0 is locally asymptotically stable if and only if $\alpha > \theta$ and $\beta > \theta$. P_0 is a saddle point and is unstable if and only if $\alpha > \theta$ and $\beta < \theta$ or $\alpha < \theta$ and $\beta > \theta$.

(ii) For the point $P_1 = (-k_2 N/\alpha; 0)$, we have

$$F_J\left(-\frac{N}{\alpha}k_2, 0\right) = \begin{pmatrix} 2k_2 + \alpha - \theta & \frac{N}{\alpha}k_2(\theta - \alpha - k_2) \\ \beta & -\beta q\frac{N}{\alpha}k_2 + \beta - \theta \end{pmatrix}. \quad (13)$$

By the same precedent argument, we can say that if $\lambda_1 = 2k_2 + \alpha - \theta < 1$ and $\lambda_2 = -k_2(\beta q N)/\alpha + \beta - \theta < 1$, meaning that if $k_2 < 0, \alpha - \theta < 1$, and $\beta - \theta < 1$, then P_1 is a local stable point of the system. Moreover, if $\lambda_1 < 0$ $\lambda_2 < 0$, then P_1 is locally asymptotically stable.

The system becomes unstable about it when $\lambda_1 < 0$ $\lambda_2 > 0$ or $\lambda_1 > 0$ $\lambda_2 < 0$ according to the Jacobian theory. In this case P_1 is considered as a saddle point. If the two zeros isoclines of the system do not intersect because of the weakness of predation effect, then U_1 wins and U_2 runs towards its extinction. The speed of this dynamic depends strictly on the value of the initials if and only if $(\alpha+\theta)/\alpha p > N(\beta-\theta)/\beta$ and $pN(\alpha + \theta)/\alpha p > (\theta - \beta)/\beta q$.

This means the subnet will forward only the first type of users' data and the second type will vanish as displayed in Figure 4.

(iii) For the point $P_2 = (0; -k_3 N/\beta)$, we have

$$F_J\left(0, -\frac{N}{\beta}k_3\right) = \begin{pmatrix} -\frac{\alpha p N}{\beta}k_3 + \alpha - \theta & \frac{\alpha p N}{\beta}k_3 \\ \frac{N}{\beta}k_3^2 - \frac{N(\beta q - \theta)}{\beta}k_3 & 2k_3 + \beta - \theta \end{pmatrix}. \quad (14)$$

It is clear that λ_1 and λ_2 signs depend on $k_3, \alpha-\theta$, and $\beta-\theta$. P_2 is a local stable point of the system when $k_3 < 0, \alpha-\theta < 1$, and $\beta-\theta < 1$ and is locally asymptotically stable if $\lambda_1 < 0$ $\lambda_2 < 0$. The system is unstable around the saddle point P_2 for $\lambda_1 < 0$ $\lambda_2 > 0$ or $\lambda_1 > 0$ $\lambda_2 < 0$. Furthermore, U_2 wins and U_1 dies as shown in Figure 3 when $(\alpha + \theta)/\alpha p < N(\beta - \theta)/\beta$ and when $pN(\alpha + \theta)/\alpha p < (\theta - \beta)/\beta q$.

(iv) For the equilibrium point $P_3 = ((\alpha p N^2 k_3 - \beta N k_2)/k_4, (-\beta q N^2 k_2 - \alpha N k_3)/k_4)$, the Jacobian eigenvalues will be

$$A = \frac{\alpha\beta}{k_4}(2k_2 - pqNk_3 - 3\alpha pNk_3) + \alpha - \theta,$$
$$B = \frac{\alpha k_3(\beta pqN^2 + 2) + \beta N k_2(2q - \beta)}{k_4} + \beta - \theta. \quad (15)$$

Let $\delta_1 = 2k_2 - pqNk_3 - 3\alpha pNk_3$, $\delta_2 = \beta pqN^2 + 2$; it follows that

$$A = \frac{\alpha\beta}{k_4}\delta_1 + \alpha - \theta,$$
$$B = \frac{\alpha k_3\delta_2 + \beta N k_2(2q - \beta)}{k_4} + \beta - \theta. \quad (16)$$

We can see that the signs of A and B depend not only on the signs of $\alpha - \theta$ and $\beta - \theta$ but also on the values and signs of k_2, k_3, k_4, δ_1, and δ_2. Supported by (5), $k_3 > 0$; then P_3 is a local stable point of the system if $\alpha-\theta < 1, \delta_1 \leq 0, \beta-\theta < 1, k_4 > 0$, $\delta_2 < 0$, and $\beta < 2q$. P_3 is stable locally and asymptotically if $A < 0$ and $B < 0$.

Knowing that P_3 is the intersection of the zeros isoclines in the first quadrant, by the Lyapunov theorem, we can conclude that each solution converges to it and the system is globally asymptotically stable as shown in Figure 5. It means that the subnet will perform normally, forwarding all data from the two types of users until both species reach the maximum capacity allowed by the subnet as (4) formalizes it.

4.3. Model Error Estimator. The 4th-order Runge-Kutta method can be used to compute the error estimator of the model.

Let $x_i = U_1$ $y_i = U_2$ and given $\{(X, Y)\}$ any solution of the system (4) will be such that $\lim_{i\to\infty} x_i = X$, and $\lim_{i\to\infty} y_i = Y$, where

$$(X, Y) = \left(\frac{(\alpha p N^2 k_3 - \beta N k_2)}{k_4}, \frac{(-\beta q N^2 k_2 - \alpha N k_3)}{k_4}\right) \quad (17)$$

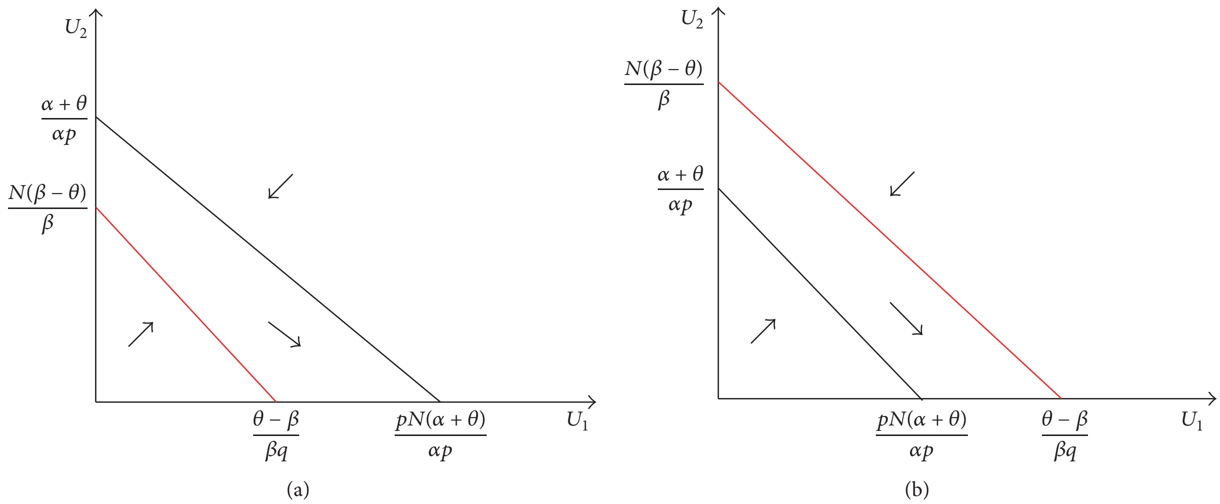


FIGURE 4: Dynamic of species 1 and species 2, respectively, when zeros isoclines do not intersect.

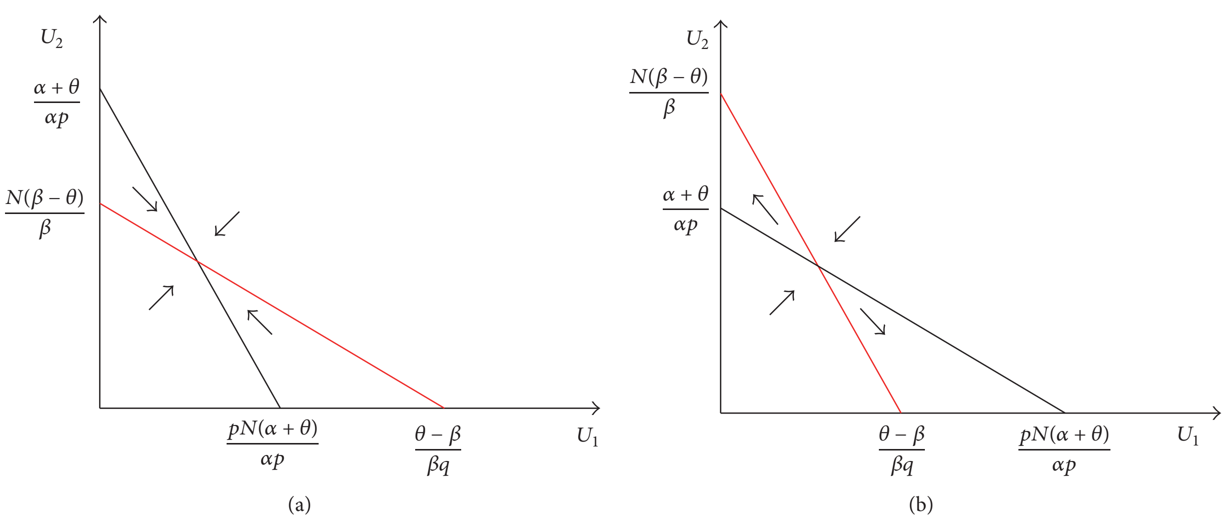


FIGURE 5: Dynamic of species 1 and species 2 when isoclines intersect. (a) shows convergence of solutions towards the unique stable equilibrium point of the system while (b) displays the vectors directions when the intersection point is an unstable point.

and $i = 0, 1, \ldots$. By setting $dy/dx = f(x, y)$, $y(0) = b$, with $b \geq 0$.

Let $y_{i+1} - y_i = (1/6)(R_1 + 2R_2 + 2R_3 + R_4)h$, $x_{i+1} - x_i = h$, with

$$\begin{aligned} R_1 &= f\left(x_i, y_i\right), \\ R_2 &= f\left(x_i + \frac{1}{2}h; y_i + \frac{1}{2}R_1 h\right), \\ R_3 &= f\left(x_i + \frac{1}{2}h; y_i + \frac{1}{2}R_2 h\right), \\ R_4 &= f\left(x_i + h; y_i + R_3 h\right), \end{aligned} \tag{18}$$

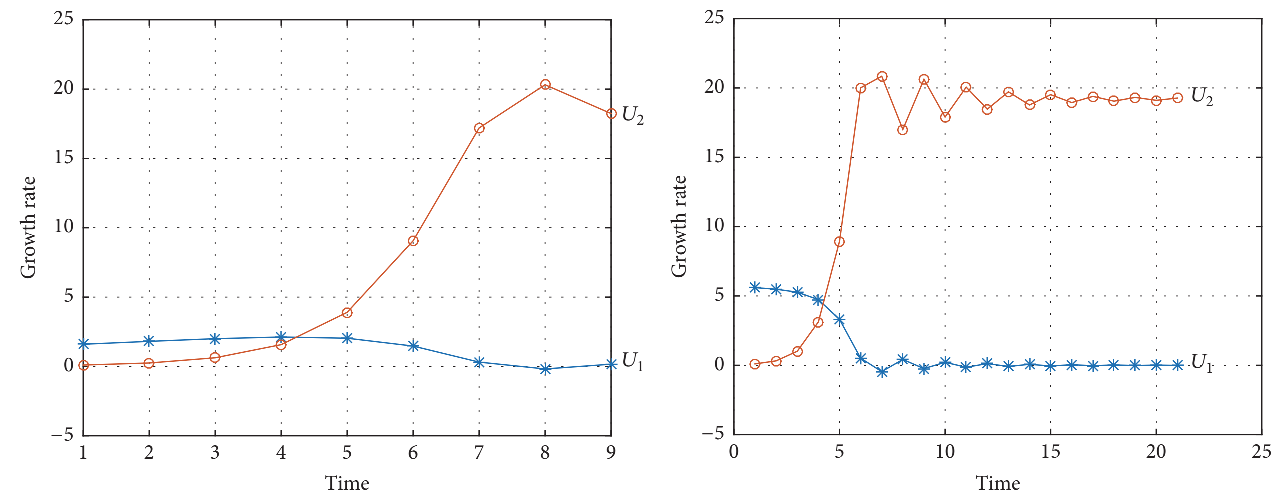
where h is a very small size step of the 4th-order Runge-Kutta; then the error estimator of the model can be computed as follows:

$$\varepsilon_i = y_{i+1} - y_i. \tag{19}$$

5. Numerical Simulation

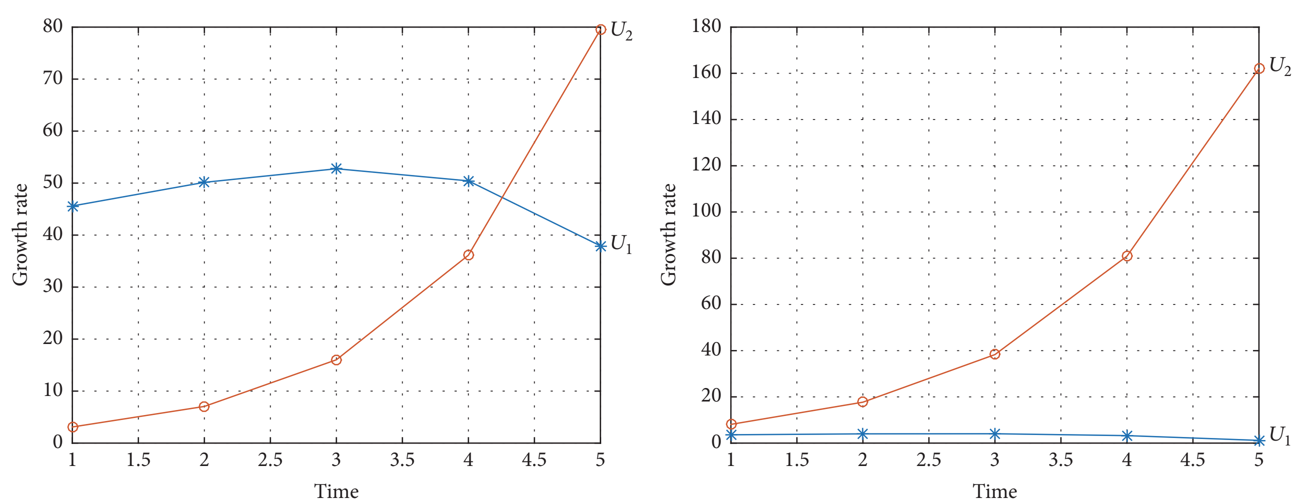
In this section, we describe computer simulations and analyze numerical results to better illustrate the initial theoretical hypothesis of our model.

5.1. Simulations. We carry out computer simulations in order to reflect as close as possible the influence data packets from OSNs' users' can have on each other at the subnet level. Our aim is to provide a new perspective on decision that might be taken for implementing adaptive routing protocol, for example, in a particular segment of the network. An Ethernet network in which all nodes on a segment see all packets transmitted by all other nodes is used in our experiment. Because of possible collisions resulting in retransmissions cycle, the network performance can be affected significantly under heavy traffic loads. A router is used to minimize each segment amount of traffic. We consider fixed all the parameters of



(a) (b)

Figure 6: Dynamic of species 1 and species 2 for (a) $U_1(0) = 1.6$, $U_2(0) = 0.1$, $\alpha = 1.5$, $N = 40$ $\theta = 0.3$, $\beta = 2.5$, $p = 0.103$, and $q = -0.18$. (b) $U_1(0) = 5.6$, $U_2(0) = 0.1$, $\alpha = 1.5$, $N = 40$ $\theta = 0.3$, $\beta = 2.5$, $p = 0.103$, and $q = -0.18$.



(a) (b)

Figure 7: Dynamic of species 1 and species 2 for (a) $U_1(0) = 3.6$, $U_2(0) = 8.1$, $\alpha = 1.5$, $N = 1000$, $\theta = 0.3$, $\beta = 2.5$, $p = 0.103$, and $q = -0.0018$. (b) $U_1(0) = 45.6$, $U_2(0) = 3.1$, $\alpha = 1.5$, $N = 1000$ $\theta = 0.3$, $\beta = 2.5$, $p = 0.103$, and $q = -0.0018$.

the model, subnet supply parameter included. We vary, slightly, the initial values of the first species in the first scenario and choose larger subnet supply and second species' initial values in the second scenario to verify the accuracy and predictability of the proposed model and explore the dynamics of competition, based on our theoretical analysis.

5.2. Results. Figures 6(a) and 6(b) show the evolutionary trend of the two users. It can be observed that species one rises only when the predators decrease. When parameters respect the stability conditions, both U_1 and U_2 speed of increase are relatively normal as shown in Figure 7(a). Because of the resources limitation and also the random behavior characteristics of the two populations, both species' growth rates have a relative sensibility over time.

We can conclude that, with higher density, species one does increase slightly before shrinking influenced by the speed of the predator even with a small density. Species two speed of increase is slightly slow where there are not enough preys to eat as shown in Figure 7(b). As mentioned above, because data are treated equally in our model, there is no special treatment to be considered by the switcher or the router in the data packets transfer process. When species two density increases exponentially, the risk of network congestion increases; as for the same window time, users send more data packets creating a longer queue at the buffer level. This result is consistent with the understanding of the real situation in that the speed of U_1 growth is conditioned by the predation and the network supply at the considered subnet. Network administrators can filter users according to the allowed bandwidth and the status of the traffic at time t and the maximum resources allowed preventing poor quality of service and congestion.

6. Conclusion

In this paper, we have proposed a two-species Lotka-Volterra system to model the interaction between two types of OSNs users by considering data packets generated at a subnet. The majority of studies on interactions between species or entities have focused on different carrying capacity and resources supposed to be unlimited. In this paper, we have analyzed the interaction phenomenon of different data packets competing to enter the subnet and to be forwarded to their destination point. We have developed a model based on classic Lotka-Volterra model to explore the behavior of this specific competition at the segment of the network the users are directly connected to. Applying the stability theory, we performed a qualitative study of the system via the differential equations. We have proved that stability can be obtained by the system if certain conditions are respected.

We have also demonstrated that different types of OSNs users can coexist even if they have to compete and their behavior is one of the main factors that can impact their global rate over time. Results of numerical simulations validated our theoretical analysis and pointed out the impact of competition on the growth speed of both populations and the importance of the initial density on this dynamic. Adopting a different routing protocol can force the coexistence of the two species to get as longer as the offered resources allow it.

The proposed model should be tested in real Social Networks with larger numbers of users and nodes to cover all the aspects of the complexity the interaction between network users can have. It will be also interesting to consider the rest of the network users as the third species and model its impact by taking into account the influence of the buffer size for instance.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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