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A Collaborative Method for Protecting Teens Against Online Predators Over Social Networks: A Behavioral Analysis

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ABSTRACT Online social networks have gained ubiquitous popularity in the last decade but despite the advantages, they have also raised privacy concerns for users. Many people have lost their jobs, relationships, and are stalked because of online privacy breaches. This situation is even more disturbing for young teens as they are in the process of learning emotional, social, and physical behaviors. Online predators take advantage of their immaturity and raise various threats to teens including aggression, rape, abduction, physical and emotional sadistic torture, and even human trafficking. Teens, on the other hand, do not have any mechanism to protect them against such threats. Therefore, this research addresses this overlooked need and proposes a trust model for the teen community, which can evaluate the trustworthiness of a stranger based on teens' psychological and social needs. This paper first identifies various factors of teen psychology from literature, and then proposes a trust model for teens based on those factors. The model ensures the trustworthiness of a stranger through a two-dimension matrix consists of his reputation in other teens and reliability. The proposed model was simulated through colored Petri nets and implemented as a real-time trust evaluation application over Facebook. A user acceptance testing was also performed by teens, which suggests that 81.77% of teens were overall satisfied with the proposed approach.

INDEX TERMS Online social networks, teen communities, online privacy, trust model.

I. INTRODUCTION

There is a rapid increase in the use of social media over the internet, particularly the acknowledgment of electronic associations [1]. Online Social Network (OSN) is a platform that provides a virtual group to individuals who want to hang out together [2]. It has become a new way to interact with friends, family, colleagues, and acquaintances over the internet [3]. OSN assembles information about users' social contacts, constructs a large interconnected social network and reflects how users are connected to others in the network [4]. As of the 1st quarter of 2020, Facebook – the most popular OSN, claims to have more than 2.6 Billion monthly active users [5]. Moreover, an average internet user spends around 2 hours and 22 minutes daily on OSN [6], meanwhile sharing

personal information 2 to 3 times a day [7]. OSN provides several advantages which drag people towards it for business and individuals' linkages, such as instant worldwide communication with friends and family, real-time information sharing, same interest groups, connection with clients, meeting new people, exploring various places, traditions and culture, and contact with loved ones [8].

However, despite the advantages, the excessive use of OSN adversely affect the social lives of people, especially teens, which is reflected by a large number of alarming problems where teens have been expelled from schools [3], [9], stalked [10], [11], bullied [12], [13], kidnapped [1] and even murdered [14], because of the content posted on OSN. Moreover, online dating frauds are on a rise which particularly affect teens at large [13] and are additionally linked to the danger of physical exploitation [13], [15], [16]. Due to such vulnerabilities and their effects on teens lives, OSNs are often

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criticized for spreading emotional instabilities [14], [17], for example, studies have claimed that teen suicide due to online emotional sufferings has become the third driving reason for the death of teenagers in the USA [12]. Explanation of such incidences is proposed by various studies which advise that these problems arise because teens spend a significant time online [12]. According to a recent study [18], spending too much time online is a major problem realized by 90% of teens. Around 81% of teens are active users of OSN [18] compared to 72% adults [18], whereas 41% teens spend an average of 9 hours a day on OSN [19].

Along with spending much time online, teens often show a lack of concern about their privacy settings [20], they add general acquaintances on their OSN profile, even people they met only once, which leads to having a lot of “friends” who may not be trustworthy [20]. This causes unnecessary revealing of information to strangers and encourages stalking [11]. Such arguments suggest that though teenage is an enthusiastic stage of life [12], but due to their simplicity, teens are inclined towards fascination [21], can be effectively spoiled by the sensual offer [13], effortlessly grasped by fraudulent [16] and cannot readily decipher between good and evil [21]. All of this makes them an easier target for online predators in situations which can be easily handled by adults. A simple breach of personally identifiable information may not be that devastating for an adult but can have frightening and awkward consequences for teens.

Getting dependent on the OSN and letting others manipulate your feelings is a serious problem that is faced by many people at some point in their lives. The other party in an online interaction can be a complete stranger and may not be trustworthy altogether. Generally, trust is important as a basic building block for every association, but when it comes to teen communities, its significance is even more as compared to adults [21]. In fact, to permit outsiders to get informed about one’s activities on OSN may prompt various security dangers. This prompts the necessity of a more secure and trustworthy environment for teens that is designed according to their psychological and behavioral needs. Thus, there is a need for teens to evaluate the trustworthiness of the communicating party (colleagues/ acquaintances/ strangers, etc.) to have a level of confidence in interactions. However, in order to pursue such a challenge, one may want to explore various characteristics of teens’ personality that differentiate them from adults and other communities. Some of these requirements are outlined below.

A. REQUIREMENTS

There are many characteristics associated with the teenage that differentiate them from adults and other communities. Some of them are listed below:

1) VIBRANT

Teens are more inclined towards social interactions, sometimes even with strangers, so there is a need for a model that dynamically adapts the vibrant nature of teens [20].

2) CONFIDENTIAL

Teens usually show less concern about their privacy while interacting with others and about revealing information that can cause harm to them [22]. Therefore, a trust model for teens should allow them to remain social but at the same time ensure that their personal information remains confidential.

3) NON-PERSISTENCE

Further, teens are usually non-persistent in their behavior which may vary with their daily mood swings [23]. Therefore, in order to interpret their true nature, the model should keep track of their general activities, habits, and behaviors over a longer period of time [23], rather than disclosing them to others after a couple of interactions.

4) COMPATIBILITY

Teens commonly develop deeper relationships with friends who are compatible with them and have similar inclinations [22], so the model should consider friends having similar preferences, nature, and interests.

5) RELIABILITY

Moreover, it is normally observed that online predators behave stealthily, as they may appear nicer to someone for a shorter period of time, but their real nature reveals after some time [24]. So, the trust model for teens should consider the long-term reliability of users interacting with teens.

6) COMMUNITY REPUTATION

Also, as suggested by Creado *et al.*, teens get confidence in their actions through community approvals [24], so the trust model should keep track of community reputation [57].

However, current trust models for OSN cannot be used for teen communities because they are not adaptive to support the vibrant nature of teens, confidentiality as well as non-persistent behavior of teens. Also, current models neither consider the psychological compatibilities nor rigorously scrutinized un-reliable behaviors of strangers [20]. Moreover, current trust models do not keep track of community reputation. Adults can handle any awkward situation in the presence of a coarse trust mechanism but a slight miscalculation of trust over a stranger may have serious harms for teens [21], [24]. Therefore, the objective of the paper is to propose an adaptive trust model for teens which can evaluate whether a stranger can be trusted or not.

The rest of the paper is ordered as follows: Section 2 presents a review of the notion of trust and its applications in related domains, section 3 presents the teens trust model and outlines its main constructs. In section 4, the proposed model is simulated using colored Petri nets, section 5 discusses the implementation details of the model as a new Facebook application. Section 6 reports the results of application evaluation by adolescents whereas section 7 concludes the whole paper.

II. RELATED WORK

The Oxford Reference Dictionary defines trust as a firm belief in the reliability, truth or strength of an entity [25]. The literature on trust is quite rich and different studies cover its various aspects. For example, Yadav *et al.* [26] asserted that eagerness to proceed with risks might be one of the rare features common to all trust circumstances. Li and Bonti [27] argued that there must be some meaningful incentives at stake and that the trusting party must be cognizant of the risk involved. Similarly, some authors [28], [29] argued that the reason behind trust having a significant impact on online interactions is its ability to cope with uncertainty. In online interactions, trust plays a significant role in helping long-term relationships among users [30]. It evolves through a series of interactions, and in case of positive end-user experiences, it stabilizes and grows, encouraging end-users to use online services more widely. Minsky [31] identified two kinds of trust i.e. regularity-based trust and familiarity-based trust. Trust based on regularity is based on the recognition that one belongs to a community known for its regularity or behavior. This type of trust is a key factor in understanding and managing the physical world, but its role in cyberspace has so far been limited due to a wide range of rules in this context. Familiarity-based trust, on the other hand, is based on personal familiarity with a person, or on the testimony of someone who is directly or indirectly familiar with that person. This type of trust is more common in online interactions and relates to the reputation of the communicating party [31].

To further explore the semantics of trust along with its application in different domains, a systematic literature review was conducted for analyzing the concept of online trust. An immensely careful search of the academic literature was undertaken in all subject areas through IEEE, Springer, ACM, Elsevier, and Emerald databases to extract renowned literature by using search strings such as “online AND trust”, “teen communities AND trust”, “trust AND social network sites”, “online trust AND social networks” etc. The result from these keywords searching yielded 40 papers on 24th July 2019. Title based screening excluded 14 articles that were irrelevant to the topic under discussion or duplicate. Further, abstract based screening, forward and backward author and reference search produced 28 resulting papers, where 7 papers discuss general trust and the remaining 21 papers were further divided into four categories: a) Trust in E-commerce, b) Trust in E-Learning, c) Trust in Mobile Ad hoc Network, and d) Trust in OSN, which are discussed below.

A. TRUST IN E-COMMERCE

Electronic-Commerce (E-commerce) is the sale/purchase of products, ventures, and information over the internet [32]. Trust is important in E-commerce because no online trading is possible without having trust between the two parties. A thorough investigation of different factors that affect the development of end-user trust in e-commerce was done by Hajli [33], where an applied structure was proposed to sort

the determining components influencing end-user trust in organizations. Similarly, Gao and Yao [34] explored various factors why customers are generally reluctant to buy online. They found that due to the virtual and unverifiable characteristics of online purchases, numerous online customers are hoodwinked, signifying the problem of trust in web-based businesses. Another research [32] discussed various trust elements to build a conceptual system portraying a trust-based leadership process where buyers can make online purchases. Moreover, Liao *et al.* [29] studied the importance of trust in different types of online interactions, with worried clients when they have difficulty controlling unauthorized disclosure or abuse of information, resulting in uncertainty and reluctance to disclose personal information.

Trust models in e-commerce cannot fulfill the trust requirements in OSNs because electronic purchases are often exercised directly from the company’s website which is usually verifiable, whereas OSN interactions are about individual people with self-reported information, which can be deceitful. The integrity of individuals is based on so many factors that cannot be comprehended by a trust model for e-commerce. Also, any wrong decision while purchasing online stuff may lead to one-time monetary loss whereas a wrong choice about trusting someone in OSN can cause irreversible iterative damages. This implies that OSN interactions are more focused on different dynamic individuals compared to learning about a particular product or service. However, this does not mean that OSN activities do not influence consumers’ purchasing decisions, as the recommendation of friends is still one of the major reasons behind trusting a particular product or company [33].

B. TRUST IN E-LEARNING

E-learning is a learning framework where learners and instructors interact through online resources [35]. Trust is important in e-learning because it provides distant and anytime learning where the instructor trusts the system for content dissemination and their assessments, while learners trust the system that the content is shared fairly and their submission is assessed equally and unbiased [36]. Tan *et al.* [37] asserted that e-learning services are broadly acknowledged as advanced learning models which can provide an adaptable and customized approach to learn. They also proposed an evaluation model based on user confidence and their ability to provide reliable e-learning services. In addition, a trusted cloud-based approach was proposed to assess the subjective trust of users in [38], along with a capacity matrix method to assess the objective trust of users. Further, Dwivedi and Bharadwaj [39] argued that e-learning recommender systems (ELRSs) have risen as the most basic mechanism to convey customized learning assets to students. ELRSs manage the problem of gigantic data adequately and provide suggestions by deliberating the students’ inclinations including their learning style, objectives, and information level [39]. In another study, Hung *et al.* studied the characteristics that influence students’ intention to share knowledge in online

learning environments. The results illustrate that learning outcomes, knowledge self-efficacy, and trust stimulate students to share their knowledge with others [40].

E-learning is a somewhat restricted environment with a single teacher-student relationship, which has its limits on the level of interactions. However, OSNs deal with multiple relationships where trust can take many forms. The trust in e-learning is significant but the scope is comparably narrow as it can only affect an instrument or a course, however, trust in OSN is of more importance as relationship stakes are high as well as multiple security risks. Therefore, trust models for e-learning environment cannot be used for OSN.

C. TRUST IN MOBILE AD HOC NETWORK

Mobile Ad Hoc Network (MANET) is characterized as a system that has many free nodes and can work without strict top-down network administration [41]. Trust is important in MANET because MANET utilizes it as a basis to exchange keys between different nodes and as a measure to set up secure administrative control [42]. Aivaloglou *et al.* [43] presented different trust developing properties in MANET and showed how they differ from trust models in other domains. They emphasized the difference by providing an example of using MANET in battlefield scenarios, but equally practical examples can be found in non-military environments. They argued that peer-to-peer networks are particularly well-suited to solve the generation, distribution, and confidence-building problems in MANET and have demonstrated the importance of developing that trust [43]. Likewise, the idea of self-sorting trust-based logical domains for dispersed control is explored in [44]. The effect of the versatility of nodes on trust foundation was considered and utilized as a method for developing trust throughout the system. In another research, Virendra *et al.* [42] introduced a security architecture based on trust domains for MANET. The purpose of their architecture was to use trust as a basis for establishing keys between nodes and use it as a measure to create secure distributed control in MANET without any predefined infrastructure. In another research effort, Goka *et al.* proposed a Distributed Management System for Trust and Reward in MANET (DMTR) which detects uncooperative nodes sending illegal traffic. DMTR uses blockchain and establishes “extraction nodes” which play a management role in the blockchain and introduce cooperative mining to accelerate settlement and maintain security [45].

The trust models in MANET deal with authenticated devices having similar behavior and precisely defined expectations, whereas every person in OSN has a different personality and behaves differently under different situations. This dynamic human nature, when combined with the dynamic nature of dyadic relations, imposes different requirements for trust compared to the requirements of trust in MANET.

D. TRUST IN ONLINE SOCIAL NETWORK

Various studies have also explored the dynamics of trust in OSNs. Trust is a vital yet unpredictable part of dyadic

connection between two elements over OSN as the accomplishment of such endeavors depends on the level of trust that individuals have in each other and in the service providers [46].

Adali *et al.* [47] presented various algorithmically quantifiable trust measures determined by the users' communication behavior over OSNs. Their study proposed that trusted communication behavior patterns are statistically different from random communication in OSNs. Further, Sherchan *et al.* [48] performed an audit of social and software engineering research on trust in the context of OSNs. They organized OSN trust in three parts: a) trust in information collection, where trust information can be gathered through three main sources: (i) behaviors, (ii) experiences, and (iii) attitudes. The collection of trust information is usually based on the user experience, but their attitudes also play a significant role in their interaction with other community members and can be seen as a source of trust information; b) trust evaluation, where an entity evaluates the trustworthiness of another entity and decides whether to trust it or not; and c) trust dissemination, where recommendation is used for trust dissemination within an OSN [48]. Moreover, Jamali and Ester [46] argued that recommender systems have become a decision-making tool to select relevant online data. Shared refining is the most prominent way to deal with building recommender frameworks and systems, and had been effectively utilized in numerous applications [49]–[51]. An OSN based recommendation system generates a user's sub-network and makes recommendations for a user in the context of other users' ratings having direct or indirect relations with the particular user. They investigated a model-based approach for recommendation in OSN, utilizing matrix factorization methods [50]. They also performed experiments on two data sets, the general population space Epinions.com dataset and Flixster.com dataset. Their results showed that demonstrating trust proliferation prompted a significant increase in recommendation precision. Moreover, in another research, He and Chu [51] reasoned that sharing of co-owned data causes some privacy problems in OSNs. They proposed a trust-based mechanism in order to collaborate with stakeholders on the control of data sharing. Their simulation results exhibited that without asking others for permission and directly posting data, the user may suffer less privacy loss if he/she considers other users' privacy [51].

Current trust models for OSN cannot be used for teen communities because the latter require a more adaptive, fine-grained, and context-sensitive model that adheres to teen psychology [27]. These requirements cannot be fulfilled by current trust models in OSN because they emphasize on general users' behaviors, generalized relationships and thus producing models based on general “friends” reputation. A slight miscalculation of trustworthiness of a stranger may not be that devastating for adults but may have serious harms for teens [21], [24]. Also, to the best of our knowledge, currently, there is no trust model that addresses the requirements posed by teen communities. As the next generation,

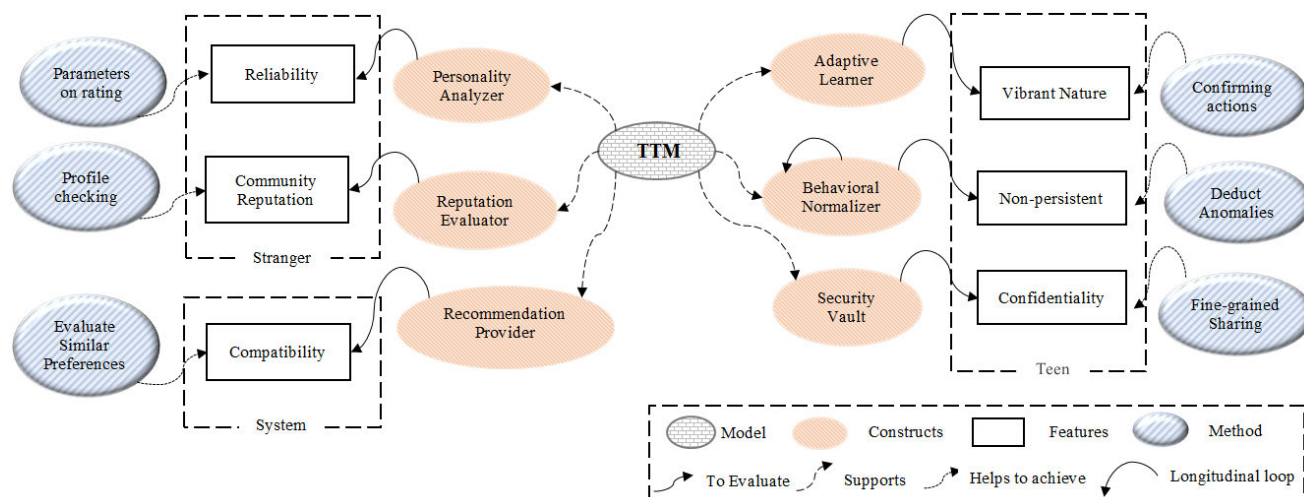


FIGURE 1. An overview of the proposed teen trust model.

teens need a sophisticated, confidential, and more trustworthy environment for the information they reveal to friends or acquaintances.

III. TEEN TRUST MODEL

From the above discussion, it seems unavoidable, for long, to neglect the need of a trust model for teen communities, that supports confidentiality as well as provides a platform for social interactions. The proposed Teen Trust model (TTM), as illustrated in Fig 1, provides an outline of the factors that affect teens’ online trust formation. TTM consists of six constructs namely: a) adaptive learner, b) behavioral normalizer, c) security vault, d) reputation evaluator, e) personality analyzer, and f) recommendation provider. The first three components support the vibrant and non-persistent nature of teens as well as provide them a secure and confidential environment to interact with their friends. The fourth and fifth components evaluate the community reputation and reliability of the stranger, whereas the last component deals with the system support to match the compatibility of the two parties involved in an online interaction. These components of TTM help to attain trust of teen communities upon strangers from three perspectives (Teens, Stranger, and System). A brief description of each of these constructs is provided below:

A. ADAPTIVE LEARNER

Adaptive learner is a component in TTM, responsible for maintaining the privacy of a teen in different situations. As discussed earlier, teens have vibrant nature [52] which can cause revelation of information to strangers based on different moods and situations. Therefore, this component readily adapts to the changing moods of a teen by not disclosing information instantly rather waiting for a couple of interactions with the other party. This is achieved through a meta- perception tool [53], which helps to generate the exact visibility of objects to other users in the system. As the views of a person could not clearly visualize by the other person,

due to the differences in various schools of thought, therefore, meta-perception helps to make judgments about what others think about the self. This component helps to visualize the same data, by two different persons, by making different judgments.

B. BEHAVIOR NORMALIZER

Behavior analysis refers to natural science that seeks to understand the behavior of individuals [54]. Behavioral normalizer module of TTM is concerned with describing, understanding, predicting, and normalizing the behavior of teens. As discussed earlier, teens’ behaviors are usually non-persistent [55], so this component normalizes such behaviors to save the revelation of information through maintaining and analyzing their long-term behavioral patterns. A behavioral pattern detection module [55] is responsible for keeping record of a teen and identify when his/her activities suddenly deviate from normal.

C. SECURITY VAULT

The proposed TTM model is expected to be fine-grained, so one can have control over who can see their information in a precise manner, i.e. it provides fine-grained confidentiality support. As discussed earlier, teens show a lack of concern about their privacy while interacting with strangers and thus easily reveal information to newly made friends, which can cause harm to them [21]. Therefore, a trust model for teens should allow them to remain social but at the same time ensures that their personal information remains confidential. This fine-grained confidentiality is achieved in TTM through a secure vault which shares less information with newly made friends even if they are in the same role as the old trusted ones.

D. PERSONALITY ANALYZER

This component of TTM concerns with analyzing the personality of a stranger. “Personality is defined as the totality of character attributes and behavioral traits of a

person” [56]. This component analyzes the personality of a stranger, whether he/she acts in a consistent manner, to verify the reliability of the stranger. Reliability is an important aspect to decide a person’s integrity through his/her activities, by figuring out whether the individual is genuinely doing what he/she claims. Reliability is important for trust because it suggests that a user acts in a consistent and honest manner by fulfilling his/her commitments. This module validates the reliability of a stranger through verifying his/her profile data. When a teen, already had some interaction with this individual offline, verify his/her personal data, this information helps other teens to analyze the integrity of the individual. This personality analysis helps teens, in general, to have a level of confidence in strangers by verifying their information through other teen users in the system. Different teens are associated with one individual by different means, so in general, each individual can be easily verified from different aspects by teens.

E. REPUTATION EVALUATOR

Reputation is the conviction that is held about somebody in a community [57]. Reputation is important for building trust because one cannot rely on his/her own experience all the time, thus he/she must rely on the judgments of others. Reputation evaluator analyzes the information provided by teenagers about a stranger. This information includes their rating information and users’ comments for them. This module provides different parameters on which a stranger can be evaluated by the teen users. The parameters include are honesty, transparency, openness, personality, and ability. The average rating of all parameters from teens is used to calculate the aggregate value, which helps a teen to identify whether a stranger is reliable or not. As discussed earlier, teens feel more confident about their actions when they get approval from the community [22], [24], [58], so TTM keeps track of the reputation of every stranger in the teen community.

F. RECOMMENDATION PROVIDER

Recommendation provider works from the system side to provide compatibility suggestions to teens. As noted earlier, teens develop deep relations with friends and colleagues who are more compatible with them and share similar inclinations [48], [52], so this component considers similarity in interests between a stranger and a teen involved in a communication. This can help to identify genuine friends and is achieved by comparing their interests and preferences.

Various constructs depicted in Fig 1 are achieved through different functions and their intersections. For example, the vibrancy of teens is diluted somewhat by the adaptive learner module through delaying the release of information to new friends. The non-persistent nature of a teen is handled through observing his/her longitudinal behavior and deducing any anomaly. Confidentiality is achieved by exposing teens’ activities after a couple of interactions. Reliability of a stranger is validated through profiling their activities over a period of time. Community reputation of a stranger

is evaluated through ratings about their behavior from other teens. Compatibility between a teen and a stranger is computed by considering their mutual interests, preferences, friends, activities, as well as friends’ recommendations. This model categorizes the contributing elements that affect the trust confidence of teens. The model helps teen communities to report numerous sources of trustworthy beliefs and represents trust online as a multi-dimensional construct that influences adolescents’ intention to interact.

IV. MODEL SIMULATION THROUGH COLORED PETRI-NET

A Petri-net, also known as Place /Transition (PT) Net, is one of the formal methods which is suitable to model discrete event systems and distributed systems [59]. Petri net formalism provides a graphical representation as well as formal verification of a system. Petri nets are capable of capturing not only the dynamic behavior but also control the flow of a system to be modeled. Petri nets are directed bipartite graphs with two kinds of nodes viz. a set of places (represented by circles) and a set of transitions (represented by rectangles) in addition to the set of arcs connecting transitions and places. Further, places model the states or passive components of a system whereas transitions are used to model the operations or active component of a system. Petri nets can be extended to high-level Petri nets which have a compact representation of complex systems. High-level Petri net with additional feature of data modeling is known as colored Petri net (CPN) [59]. An interactive simulation in CPN allows us to observe the control flow as well as data flow in the model to study different scenarios in detail and to verify whether the model works as expected.

The proposed model (TTM) was also simulated in CPN as presented in Fig 2. In the simulation, only string and Boolean variables were used to pass the tokens through different stages. A request function was defined as an arc inscription on the ongoing arc of transition “request”. The simulation of the model was performed by the Boolean value of the variable “trust” in a request function. To initiate the simulation, a token either “true” or “false” is moved forward through different places, until the teenager wants to interact with a stranger. However, after intended to interact, if the teenager wants to continue the interaction by making him/her a friend, then a true token is passed towards “if yes” transition, otherwise, a false token is passed to the “do not interact” place.

The Petri net model depicts some of the concepts upon which trust can be established between teenagers and strangers. The model begins with a transition i.e. “request”, where no trust among teenagers and strangers is yet established and the teenager only receives a request from the stranger. By firing this transition, request function returns one of the Boolean values, because at this point, the teenager is still deciding whether he/she wants to interact with the stranger or not, for making him/her a friend by accepting his/her request. Therefore, either one of the Boolean values is passed to the place “intention to interact” which reflects that

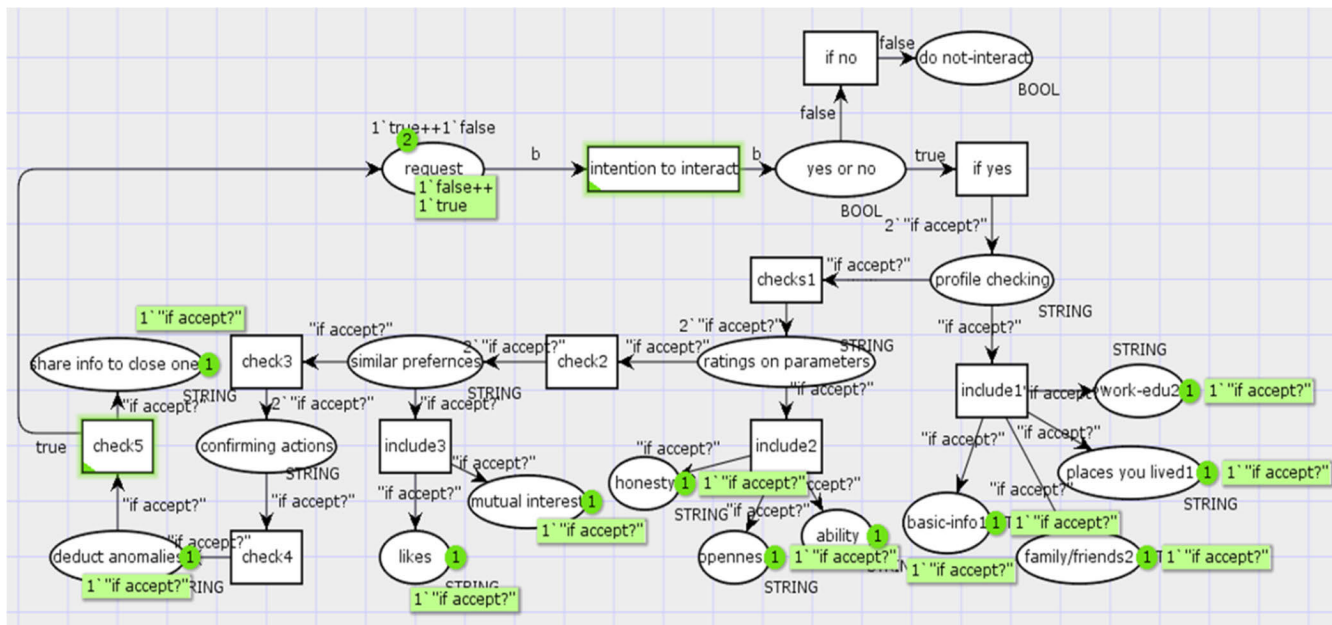


FIGURE 2. Colored Petri net model for TTM.

the teenager is either ready or not for interaction. Now, if the teenager makes the decision to interact and make him/her a friend, then the teenager has to explore stranger’s life through various factors outlined above, e.g. profile checking, ratings on parameters, similar preferences, share information to close ones, deduct anomalies, and confirming actions. These places help the teenager to evaluate whether the stranger is loyal, trustworthy, and reliable to become a friend. The transition “if yes” is fired to continue the relationship and add the stranger as the teenager’s friend. If prior to this stage, the teenager is not satisfied enough to continue with the relationship, a “false” token is passed to “do no interact” place, to ensure that the teenager does not want to make friendship with the stranger. However, even if there is no association between the teenager and the stranger, both can remain part of the OSN.

In the case of friendship, a string type token is passed to the next places one by one, in order to check the factors of teenagers and strangers. These factors include “profile checking”, “ratings on parameters”, “similar preferences”, “share info to close ones”, “deduct anomalies” and “confirming actions”. A teenager can check all the previous experiences of the stranger and a string type token is moved one by one to all the successor places of “profile checking” by firing the transition “include1”. This process is modeled to check stranger’s work and education, places he/she has been lived, family/friends and all the basic information. The token that was passed to the “rating on parameters” place, enables the “include2” transition. The teenager checks the rating of the stranger given by other teenagers. As discussed above, “rating on parameters” involves parameters of honesty, openness, ability, and skills. On the basis of these factors, other

teenagers (who had any interaction with this stranger in the past) had already rated the stranger. After checking this, the token is passed to check “similar preferences” place, enables the “include3” transition. Passing through each place, the model checks the similarity of interests between teenager and stranger.

Further, the token is passed to the place, “confirming actions”, here the model is conscious to check that either teenager is not revealing his/her information readily to the stranger or giving the second chance to consider the reputation of the stranger. Then, the token is passed to “deduct anomalies” of teens, by computing personality type. After that, the token is passed to check either teen is sharing more information with old friends or less sharing with new friends. After passing through all the levels, the teenager can make a perception of the stranger and can also provide his/her own opinion. In the CPN model presented in Fig 2, there is a loop, which again turns back to the original state after checking all the levels to ensure the completion of a single iteration of the trust-building process before the start of next iteration. Each iteration of the CPN model demonstrates that the teenager can modify his/her previous rating for the stranger in the lights of new experiences to provide better reputation availability to the community.

The simulation also generated a reachability graph and state-space report as depicted in Fig 3 and Appendix II respectively. A partial state space was generated through the simulation of the CPN model for 10 seconds. There are 3413 nodes and 11797 arcs in the partial reachability graph (see Appendix II). With the help of the state space report, several important behavioral properties of the model can be verified.

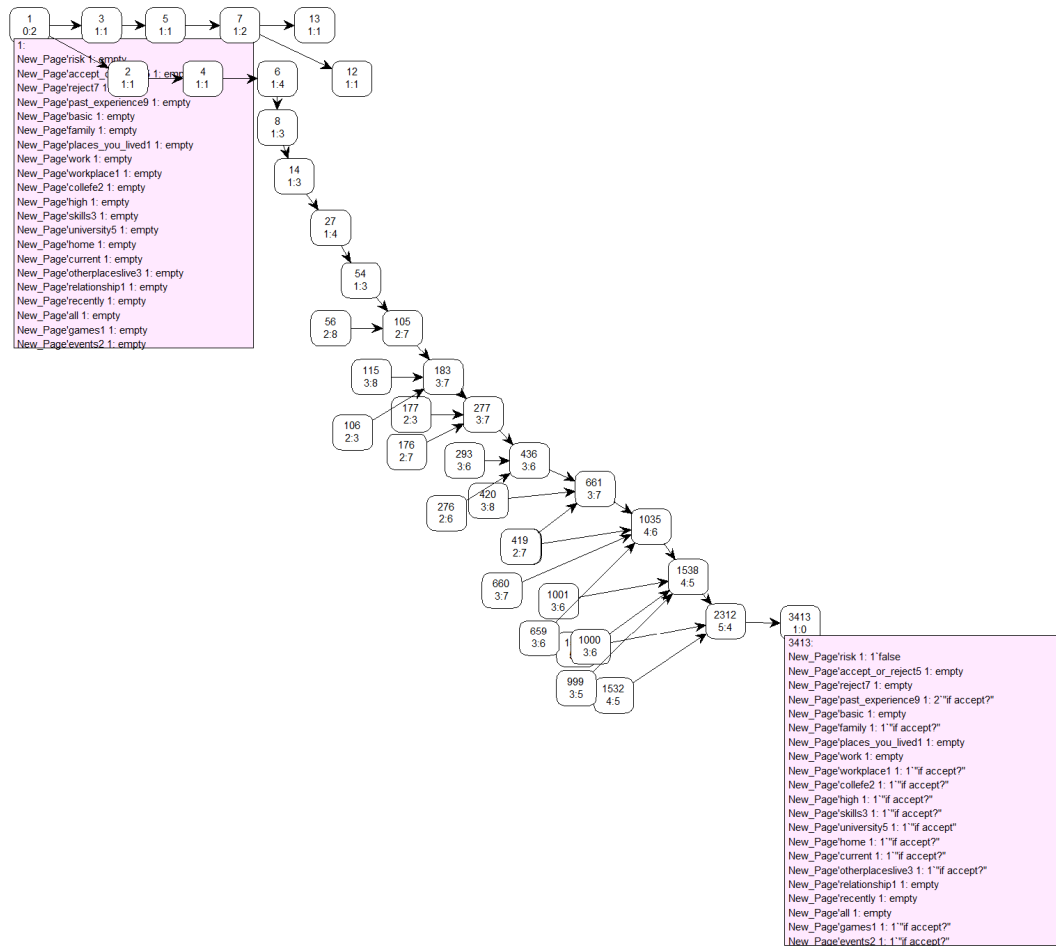


FIGURE 3. Partial Reachability Graph with Description of Each Node.

It is clear from the state space report that few places in the CPN model (e.g. relationship, games, events, hometown, etc.) are not bounded.

There are several dead markings present in the report, which are actual final markings of the trust-building process. Further, there is no dead transition instance which shows the smooth execution of the model. There is no infinite firing sequence of the transitions in the CPN model, which is derived through the fairness property in the model. Further according to the state space report, there does not exist a home marking which leads to the fact that initial marking cannot be reached from any other reachable marking.

Fig 3 represents the partial reachability graph [53] of the CPN simulation, which provides the analysis of the proposed CPN model. The partial reachability graph shows the directed path from initial marking viz. state 1 to marking 3413 represented by node 3413. It is also depicted that there is no successor node of marking number 3413 which is one of the final reachable markings for the performed simulation.

V. MODEL IMPLEMENTATION

The TTM was also implemented as a Facebook application to observe whether such initiative is actually desired by the teen

community. The details of this implementation are discussed in this section.

The application was developed using .Net at server-side and SQL Server for backend data storage. Entity Framework 6.0 was used to communicate with the data storage repository. When a user clicks on the Facebook application button, it initiates the route redirect request, which in turn invokes our Facebook application home controller’s index action. The application is divided into different components: a) classes details are fetched from Facebook Application Programming Interface (API); b) the helper functions cleans the data fetched from the API, performs pagination for data fetching, and converts it into the classes defined in the first component; and c) business class performs all the database related tasks such as fetching, saving, searching, and deleting of data, etc. Separate classes for each type of data were defined to fetch user object, user likes, user movies, user music, etc. When a user requests the application server’s home controller index action, he/she is requested to grant the permissions required for filling the data. These permissions are needed for compatibility analysis and include his/her personal details, friends list, movie, and music like, etc. After taking the permissions and fetching the user’s data, the helper function creates a

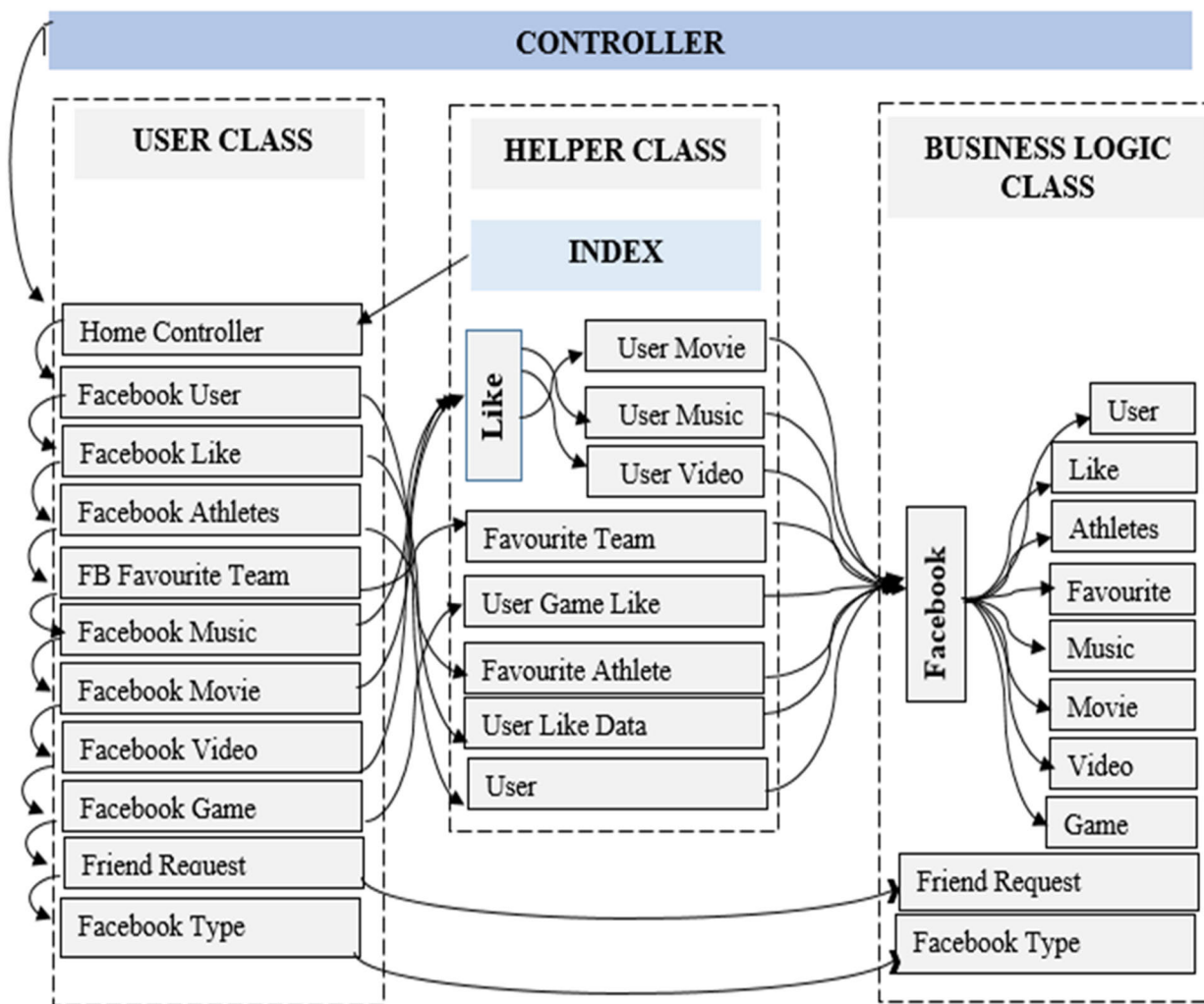


FIGURE 4. Architecture of Facebook application.

new instance of user class and maps JSON user object to the user class object and returns the request to the home controller’s index action. After this, the user business class is invoked for saving the user class object data in storage repository i.e. SQL Server. After fetching and storing the user object, the same process is followed for different ‘likes’ classes including movies, athletes, videos, teams, etc. Each class has its own similar helper function and business class, as discussed earlier for the user object. The working of the application is illustrated in Fig 4.

The screenshots of the application are shown in Fig 5. In Fig 5(a), the home page of a user is shown where all her friends, likes, music, etc. have been shown in the form of an extendable list, and the friend requests from other users also appear at the top right corner. Fig 5(b) shows friends, music and other details about the user in detail after exemplifying an extendable list. From this screen, the user can also see the rating of her friends. In Fig 5(c), the list of users who have joined the application is shown. From this screen, a user

can send friend requests to other users as well as add them to his/her friend list after analyzing their overall rating given by other teens, as shown in Fig 5(d).

To emphasize the rationale of the model along with its need and significance, all the trust models discussed in section 2 are now compared with the proposed model on the basis of the requirements discussed in section 1. The requirements are: (a) vibrancy, (b) persistence, (c) confidentiality, (d) reliability, (e) community reputation, and (f) compatibility. Table 1 provides the characteristics of different trust models present in literature and compares them on the basis of trust requirements of the teen-communities.

Table 1 also reflects that various characteristics present in literature have different significance in different research domains. It also presents research gaps where future trust models can pay more attention and explore interesting insights about users’ behaviors. For instance, it can be deduced that general trust models support vibrancy, reliability, and confidentiality but less attention has been given to

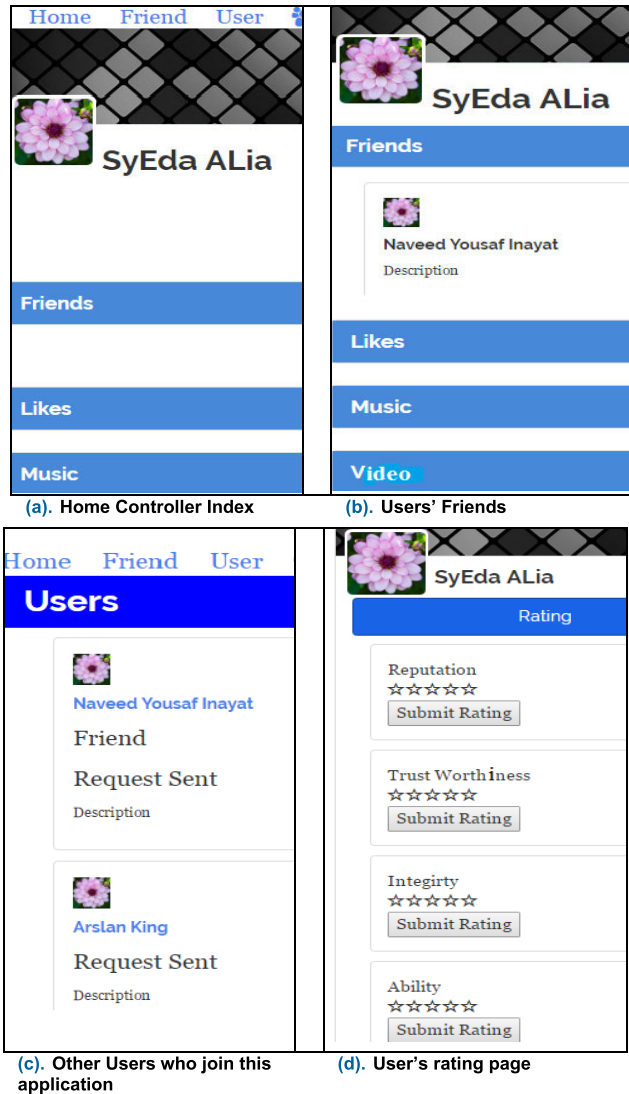


FIGURE 5. Different Views of Facebook application.

persistency, recommendation, and reputation characteristics. These types of models without recommendation and reliability cannot accommodate indirect trust and cannot compose trust information received from different channels. Likewise, the trust models in E-Commerce domain support vibrancy, persistence, confidentiality, and reliable but pay less attention to recommendation and reputation characteristics. These types of models without recommendation and reputation cannot establish trust over time and do not speculate the direct impact of the preferences of trustee on calculated trust value. Similarly, E-Learning trust models support vibrancy, persistence, recommendation, and confidentiality, but less attention has been given to reliability and reputation. The models without reliability and reputation cannot gradually establish trust over time, do not speculate the direct influence of the preferences of trustee on calculated trust value and cannot compose trust information received from different channels, but from a single source only.

TABLE 1. Comparison among existing and proposed trust model.

Categories in Trust	Current Trust Models	Vibrancy	Persistency	Confidentially	Reliability	Compatibility	Community Reputation
General Trust	[26]			✓	✓		
	[27]		✓	✓	✓		✓
	[28]				✓		✓
	[30]			✓			
	[31]			✓	✓	✓	
E-Commerce	[29]				✓		
	[32]			✓			
	[33]			✓	✓		
	[34]			✓	✓		
E-Learning	[35]			✓			
	[36]			✓			
	[37]				✓		
	[38]			✓	✓	✓	
	[39]				✓		
MANET	[40]	✓				✓	
	[41]			✓	✓		✓
	[42]				✓	✓	
	[43]				✓	✓	
	[44]				✓	✓	
Online Social Networks	[45]	✓		✓			✓
	[46]				✓		
	[47]				✓		✓
	[48]				✓	✓	✓
	[49]				✓	✓	✓
	[50]				✓	✓	✓
	[51]				✓	✓	✓
TTM		✓	✓	✓	✓	✓	✓

Additionally, the trust models in MANET support vibrancy, persistence, and reliability but less attention has been given to reputation, recommendation, and confidentiality. The models which do not support reputation and confidentiality do not provide the freedom to the other person to have one-way trust relationship as well as cannot accommodate indirect trust. Similarly, existing trust models in OSN support vibrancy, persistence, reliability, and confidentiality but less attention has been paid on recommendation and reputation. These models without recommendation cannot accommodate trustee's preferences as well as the context of the situation while developing the trust between users.

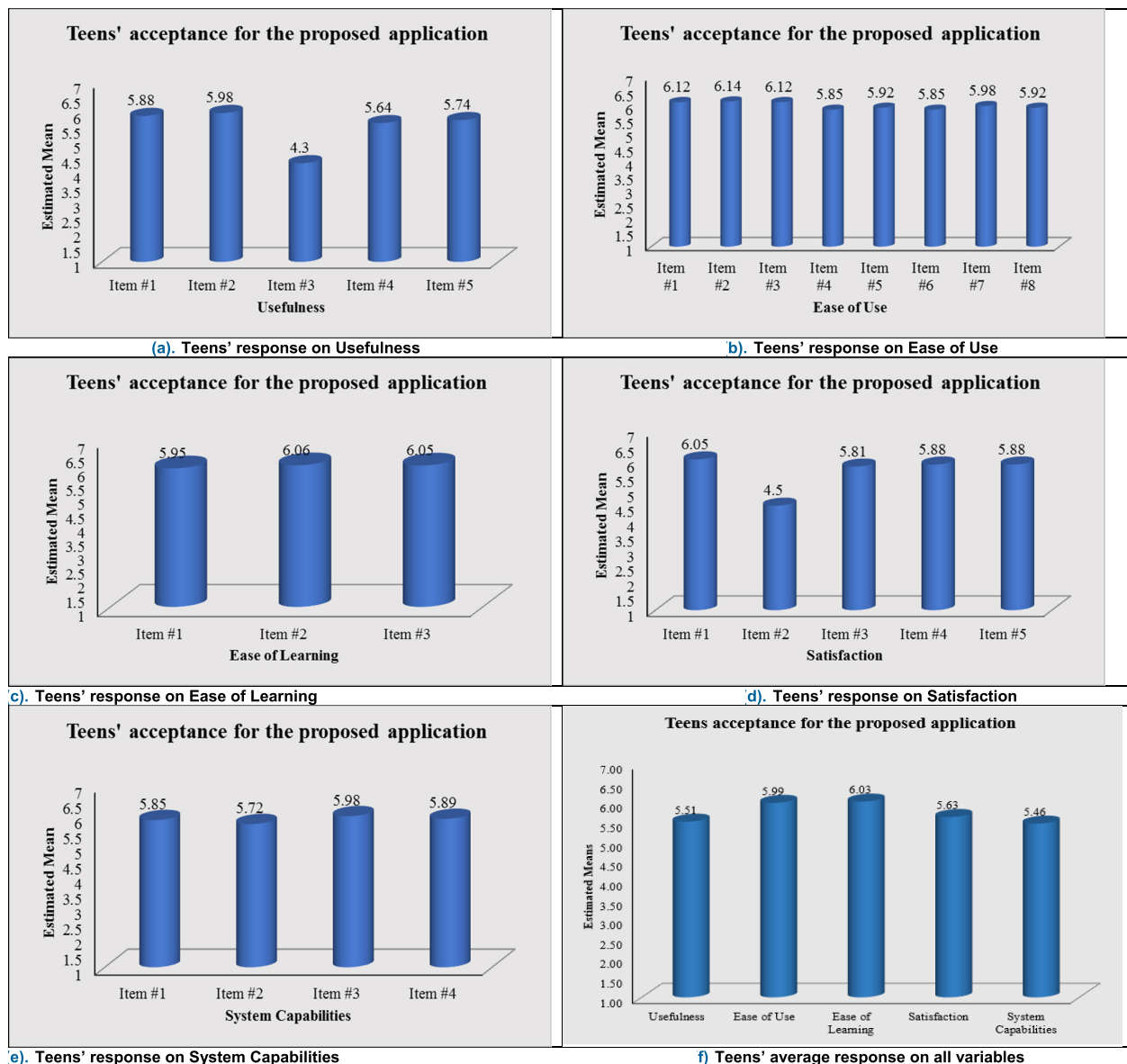


FIGURE 6. Teens’ response on the proposed application.

VI. DATA ANALYSIS AND RESULTS

The Facebook application, developed on the TTM model, was also evaluated through teens as the basic aim of this research was to find whether a trust model for teenagers can help them to find trustworthy connections. For this purpose, an experiment was designed and conducted, where a total of 118 teenagers (65 males and 53 females) used the application and filled the questionnaire.

The questionnaire consisted of five variables including usefulness, ease of use, ease of learning, satisfaction, and system compatibility, with a total of 25 questions. A 7-point Likert scale was used to cover a large domain of responses from the respondents and ranged from strongly disagree (1) to strongly agree (7). To validate this section, the questionnaire was adapted from [60], where the average Cronbach’s alpha value of 0.88 reflects good internal consistency.

TABLE 2. Inter-variable correlation.

	Usefulness	Ease of Use	Ease of Learning	Satisfaction	System Capabilities
Usefulness	–	0.74	0.72	0.70	0.68
Ease of Use		–	0.87	0.82	0.77
Ease of Learning			–	0.78	0.75
Satisfaction				–	0.83
System Capabilities					–

The confidentiality of the respondents was ensured through not taking any personally identifiable information because it is realized that people’s consciousness can also influence

TABLE 3. (a). Inter-item Correlation among all the variables. (b). Inter-item correlation among all the variables.

	Usefulness					Ease of Use								
		U1	U2	U3	U4	U5	EU1	EU2	EU3	EU4	EU5	EU6	EU7	EU8
Usefulness	U1	–	0.66	0.22	0.47	0.48+	0.43	0.35	0.45	0.36	0.46	0.44	0.34	0.36
	U2	0.66	–	0.40	0.67	0.60	0.51	0.51	0.47	0.42	0.55	0.5	0.45	0.54
	U3	0.22	0.40	–	0.49	0.40	0.46	0.36	0.49	0.29	0.39	0.44	0.52	0.43
	U4	0.47	0.67	0.49	–	0.65	0.45	0.44	0.50	0.54	0.61	0.62	0.51	0.65
	U5	0.48	0.60	0.40	0.65	–	0.50	0.44	0.52	0.50	0.56	0.49	0.40	0.52
Ease of Use	EU1	0.43	0.51	0.46	0.45	0.50	–	0.80	0.58	0.64	0.61	0.56	0.52	0.57
	EU2	0.35	0.51	0.36	0.44	0.44	0.80	–	0.60	0.60	0.64	0.58	0.50	0.64
	EU3	0.45	0.47	0.49	0.50	0.52	0.58	0.60	–	0.47	0.58	0.52	0.55	0.51
	EU4	0.36	0.42	0.29	0.54	0.50	0.64	0.60	0.47	–	0.59	0.55	0.60	0.63
	EU5	0.46	0.55	0.39	0.61	0.56	0.61	0.64	0.58	0.59	–	0.65	0.62	0.70
	EU6	0.44	0.50	0.44	0.62	0.49	0.56	0.58	0.52	0.55	0.65	–	0.68	0.74
	EU7	0.34	0.45	0.52	0.51	0.40	0.52	0.50	0.55	0.60	0.62	0.68	–	0.70
	EU8	0.36	0.54	0.43	0.65	0.52	0.57	0.64	0.51	0.63	0.70	0.74	0.70	–
Ease of Learning	EL1	0.56	0.57	0.36	0.59	0.57	0.66	0.57	0.48	0.65	0.59	0.70	0.61	0.75
	EL2	0.46	0.48	0.39	0.50	0.46	0.64	0.63	0.56	0.55	0.62	0.68	0.63	0.63
	EL3	0.39	0.56	0.49	0.69	0.55	0.61	0.60	0.57	0.61	0.6	0.71	0.74	0.76
Satisfaction	S1	0.58	0.65	0.41	0.52	0.64	0.67	0.59	0.64	0.62	0.61	0.59	0.67	0.63
	S2	0.35	0.50	0.42	0.53	0.48	0.49	0.55	0.40	0.56	0.57	0.56	0.63	0.70
	S3	0.38	0.36	0.19	0.33	0.48	0.53	0.52	0.33	0.71	0.49	0.40	0.42	0.47
	S4	0.45	0.46	0.36	0.49	0.53	0.54	0.52	0.43	0.67	0.59	0.51	0.66	0.60
	S5	0.55	0.59	0.45	0.61	0.60	0.59	0.56	0.53	0.65	0.63	0.64	0.71	0.70
System Capabilities	SC1	0.45	0.53	0.36	0.50	0.41	0.49	0.51	0.35	0.59	0.58	0.61	0.64	0.77
	SC2	0.55	0.59	0.45	0.61	0.41	0.59	0.56	0.53	0.65	0.63	0.64	0.71	0.70
	SC3	0.56	0.56	0.41	0.58	0.54	0.58	0.50	0.56	0.71	0.62	0.58	0.64	0.61
	SC4	0.42	0.51	0.44	0.50	0.51	0.42	0.51	0.59	0.41	0.53	0.46	0.47	0.47

their honesty and introduces prestige bias [23]. Also, the identities were not important for the results and do not serve any purpose. Participants had sufficient time to respond as the questionnaires were collected the next day. No incentive was offered to participants for filling the questionnaires. A brief description of the research variables is as follow:

Usefulness evaluates that teens get benefit from the application. This variable included items like “This application helps me to be more effective” and “This application does everything I would expect it to do”. The items were adapted from [60] for validation and a Cronbach’s alpha value of 0.82 for usefulness suggests good internal consistency.

Ease of use is the measurement of how easy the finished product is to be used by its intended users [38, 53]. This variable was enquired through items like “The application is simple to use” and “I can use the application without written instructions”. The items were adapted from [60] for

validation and a Cronbach’s alpha value of 0.92 for ease of use suggests good internal consistency.

Ease of Learning is the need to recognize to overcome user resistance [39]. This variable was investigated through items like “I easily remember how to use the application” and “I learn to use the application quickly”. The items were adapted from [60] for validation and a Cronbach’s alpha value of 0.88 suggests good internal consistency.

Satisfaction is the fulfillment of a need [38]. Here, it determines whether the application satisfies the teen users or not. The items for this variable included “I am satisfied with the application” and “I would recommend a friend about the application”. The items were adapted from [60] for validation and a Cronbach’s alpha value of 0.91 suggests good internal consistency.

Compatibility is the capacity of different components of a system to work together without having to be altered to

TABLE 3. (Continued.) (a). Inter-item Correlation among all the variables. (b). Inter-item correlation among all the variables.

		Ease of Learning			Satisfaction					System Capabilities			
		EL1	EL2	EL3	S1	S2	S3	S4	S5	SC1	SC2	SC3	SC4
Usefulness	U1	0.56	0.46	0.39	0.58	0.35	0.38	0.45	0.55	0.45	0.55	0.56	0.42
	U2	0.57	0.48	0.56	0.65	0.50	0.36	0.46	0.59	0.53	0.59	0.56	0.51
	U3	0.36	0.39	0.49	0.41	0.42	0.19	0.36	0.45	0.36	0.45	0.41	0.44
	U4	0.59	0.50	0.69	0.52	0.53	0.33	0.49	0.61	0.50	0.61	0.58	0.50
	U5	0.57	0.46	0.55	0.64	0.48	0.48	0.53	0.60	0.41	0.41	0.54	0.51
Ease of Use	EU1	0.66	0.64	0.61	0.67	0.49	0.53	0.54	0.59	0.49	0.59	0.58	0.42
	EU2	0.57	0.63	0.6	0.59	0.55	0.52	0.52	0.56	0.51	0.56	0.50	0.51
	EU3	0.48	0.56	0.57	0.64	0.40	0.32	0.43	0.53	0.35	0.53	0.56	0.59
	EU4	0.65	0.56	0.61	0.62	0.56	0.71	0.67	0.65	0.59	0.65	0.71	0.41
	EU5	0.59	0.62	0.6	0.61	0.57	0.49	0.59	0.63	0.58	0.63	0.62	0.53
	EU6	0.71	0.68	0.71	0.59	0.56	0.40	0.51	0.64	0.61	0.64	0.58	0.46
	EU7	0.61	0.63	0.74	0.67	0.63	0.42	0.66	0.71	0.64	0.71	0.64	0.47
	EU8	0.75	0.63	0.76	0.63	0.70	0.47	0.60	0.70	0.71	0.70	0.61	0.47
Ease of Learning	EL1	–	0.69	0.77	0.75	0.67	0.48	0.61	0.71	0.63	0.71	0.67	0.45
	EL2	0.69	–	0.70	0.63	0.48	0.47	0.57	0.68	0.62	0.68	0.54	0.46
	EL3	0.77	0.70	–	0.70	0.64	0.44	0.60	0.74	0.65	0.74	0.66	0.53
Satisfaction	S1	0.75	0.63	0.70	–	0.70	0.60	0.69	0.80	0.63	0.78	0.73	0.61
	S2	0.67	0.48	0.64	0.70	–	0.50	0.70	0.60	0.66	0.65	0.58	0.48
	S3	0.48	0.47	0.44	0.60	0.50	–	0.70	0.60	0.60	0.62	0.64	0.43
	S4	0.61	0.57	0.60	0.69	0.70	0.70	–	0.80	0.67	0.75	0.70	0.49
	S5	0.71	0.68	0.74	0.80	0.60	0.60	0.80	–	0.79	0.73	0.74	0.56
System Capabilities	SC1	0.63	0.62	0.65	0.63	0.66	0.60	0.67	0.79	–	0.91	0.67	0.48
	SC2	0.71	0.68	0.74	0.78	0.65	0.62	0.75	0.73	0.91	–	0.95	0.60
	SC3	0.67	0.54	0.66	0.73	0.58	0.64	0.70	0.74	0.67	0.95	–	0.57
	SC4	0.45	0.46	0.53	0.61	0.48	0.43	0.49	0.56	0.48	0.60	0.57	–

U1-U5 refers to Usefulness, EU1-EU8 refers to Ease of Use, EL1-EL3 refers to Ease of Learning, S1-S5 refers to Satisfaction and SC1-SC4 refers to System Capabilities

do so [38]. Here, it investigates whether the application is compatible with teens or not. The items for this variable included “Is the application designed for all level of users”, “Is the application reliable” etc. The items were adapted from [60] for validation and a Cronbach’s alpha value of 0.85 suggests good internal consistency.

The purpose of this activity was to estimate the response of adolescents to the proposed question in order to determine their confidence and comfort level if the demand was introduced into the current OSN. To determine the reliability of the variables, a correlation analysis was performed between the variables, as shown in Table 2, which shows that all the variables are significantly correlated. Also, to determine the reliability of the items in each variable, a correlation analysis was performed between all the items. The elements of each

variable were found to be statistically correlated as shown in Table 3 (a and b). Inter-item and inter-variable correlation analysis examine how scores on one element are related to scores on all the other elements [61]. It provides an evaluation of product redundancy, the extent to which elements of a scale evaluate the same content [61]. Table 3 (a and b) reflects the inter-item correlation of all the variables under consideration i.e., Usefulness, Ease of Use, Ease of Learning, Satisfaction, and System Capabilities. The bold digits show the inter-item correlation within a variable, whereas the remaining digits show the inter-item correlation with all the items of other variables. These values show that the items within each variable are statistically significantly correlated.

Below, in Table 4, the mean of different items for each variable is shown, along with their independent Cronbach’s alpha

TABLE 4. Average (Mean), Cronbach’s alpha and standard deviation of different items for each variable.

	Usefulness	Ease of Use	Ease of Learning	Satisfaction	System Capabilities
Item #1	5.88±1.2 3	6.12±1.0 6	5.95±1.2 7	6.05±1.2 2	5.85±1.3 7
Item #2	5.98±1.0 6	6.14±1.0 5	6.06±1.1 1	4.5±0.78	5.72±1.5 1
Item #3	4.30±0.7 1	6.12±1.0 1	6.05±1.2 2	5.81±1.3 3	5.98±1.1 4
Item #4	5.64±1.2 6	5.85±1.1 7		5.88±1.2 6	5.89±1.0 6
Item #5	5.74±1.2 8	5.92±1.1 0		5.88±1.2 9	
Item #6		5.85±1.2 8			
Item #7		5.98±1.1 0			
Item #8		5.92±1.2 5			
Variable Mean	5.50±0.8 8	5.99±0.9 1	6.02±1.0 8	5.62±1.0 1	5.86±1.0 6
Cronbach’s Alpha	0.84	0.92	0.88	0.91	0.85

values. Cronbach’s Alpha is a measure of internal coherence, i.e., how closely a set of elements are related as a group [62]. We considered a measure of the reliability of the scale.

Table 4 shows the Mean, Standard Deviation, and Cronbach’s Alpha among all the items and variables. The acceptable range of Cronbach’s alpha is 0.70 to 0.90 [62], which shows the internal consistency among items of a variable. So, the results of Cronbach’s Alpha values, shown in Table 4, demonstrate that each individual item in the scale statistically significantly correlates with the sum of the remaining items. Fig 6 (a – f) shows the average response of teen users for all variables.

- 1) Fig 6(a) shows the average teens’ response on usefulness (with its items combined). The graph shows that the response range is between 4.3 to 5.98, which reflects that teens have a 61% to 85% perception of usefulness towards the application.
- 2) Fig 6(b) shows the average teens’ response on Ease of Use (with its items combined). The graph shows that the response range is between 5.85 to 6.14, which reflects that teens have 83% to 87% perception of ease of use about the application.
- 3) Fig 6(c) shows the average teens’ response on Ease of Learning (with its items combined). The graph shows that the response range is between 5.95 to 6.06, which reflects that teens have 85% to 86% likeliness of ease of learning towards the application.
- 4) Fig 6(d) shows the average teens’ response on satisfaction (with its items combined). The graph shows that the response range is between 4.5 to 6.05, which reflects that teens have 64% to 86% likeliness of satisfaction with the application.

- 5) Fig 6(e) shows the average teens’ response on System Capabilities (with its items combined). The graph shows that the response is between 5.72 to 5.98, which reflects that teens have 81% to 85% positive perception about the system capabilities.
- 6) Fig 6(f) shows the average teens’ response on all variables (with their items combined), i.e., usefulness, ease of use, ease of learning, satisfaction and system capability. The graph shows that for every variable, the value of teens’ response is between 5.5 to 6.3, which reflects that teens have almost 78% to 90% likeliness towards the application.

VII. CONCLUSION

This paper explores various problems of teens which they face online including stalking [11], cyberbullying [13], kidnapping [14], online frauds [13], etc. and realizes that they can be handled through a more trustworthy online environment. For this purpose, this paper reviews and investigates various factors that influence teenagers’ trusting beliefs in online interactions. Further, a teen trust model (TTM) is proposed which evaluates the reputation of strangers in the teen community. The proposed model supports vibrant and non-persistent nature of teens, offers confidentiality, evaluates reliability and community reputation of strangers as well as provides compatibility between a teen user and a stranger. The model helps teens to address different sources of trust beliefs and represents online trust as a multi-dimensional construct that influences the user’s intention to create interactions. In this model, a stranger is judged by its multidimensional reputation rating which is given by other teens, based on different features as discussed above. Further, the proposed model (TTM) was also simulated in CPN, which generates a reachability graph and state-space report and provides an analysis of the proposed CPN model. The graphs suggest that there is no dead transition instance which shows the smooth execution of the model. Also, there is no infinite firing sequence of the transitions in the CPN model, which reflects the fairness property of the model. Moreover, a Facebook application based on the proposed model was also developed and evaluated through 118 teen users on the basis of usefulness, ease of use, ease of learning, satisfaction, and system capability. Overall, teens were 78% to 90% satisfied with the proposed application. Further, the system was designed to provide information confidentiality to teens against strangers. As reflected by the results, the correlation between system capabilities and teens’ satisfaction is 83%, therefore, the proposed model seems to achieve the hypothesized goal.

The results achieved in this research also confirm that the previous literature is consistent in claiming that the lack of user trust in online communities is one of the main causes of OSN failures. This paper addresses the problem of individual trust but if teens interact with each other in the form of groups, further research may be needed to explore

Teen Trust Application Survey

Contact Email: ahsamreen123@gmail.com

Please take a few minutes to fill out this survey on your use of "Teen Trust Application". This application is basically a reputation management system which ensures a teenager that to trust a stranger or not???

I welcome your feedback and your answers will be kept confidential. Thank you for your participation.

Try to respond to all the items.

The sequence of items is

1. Strongly Disagree 2. Slightly Disagree 3. Disagree 4. Neutral 5. Slightly Agree 6. Agree 7. Strongly Agree

USEFULNESS		1	2	3	4	5	6	7	NA
1. This application helps me be more effective. <input type="checkbox"/>	strongly disagree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	strongly agree <input type="radio"/>
2. This application is useful. <input type="checkbox"/>	strongly disagree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	strongly agree <input type="radio"/>
3. This application saves my time when I use it. <input type="checkbox"/>	strongly disagree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	strongly agree <input type="radio"/>
4. This application does everything I would expect it to do. <input type="checkbox"/>	strongly disagree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	strongly agree <input type="radio"/>
5. This application helps me be more productive. <input type="checkbox"/>	strongly disagree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	strongly agree <input type="radio"/>

EASE OF USE		1	2	3	4	5	6	7	NA
6. This application is easy to use. <input type="checkbox"/>	strongly disagree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	strongly agree <input type="radio"/>
7. This application is simple to use. <input type="checkbox"/>	strongly disagree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	strongly agree <input type="radio"/>
8. This application is user friendly. <input type="checkbox"/>	strongly disagree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	strongly agree <input type="radio"/>
9. This application requires the fewest steps possible to accomplish what I want to do with it. <input type="checkbox"/>	strongly disagree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	strongly agree <input type="radio"/>
10. This application is flexible. <input type="checkbox"/>	strongly disagree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	strongly agree <input type="radio"/>
11. I can use the application without written instructions. <input type="checkbox"/>	strongly disagree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	strongly agree <input type="radio"/>
12. Both occasional and regular users would like this application. <input type="checkbox"/>	strongly disagree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	strongly agree <input type="radio"/>
13. I can use this application successfully every time. <input type="checkbox"/>	strongly disagree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	strongly agree <input type="radio"/>

EASE OF LEARNING		1	2	3	4	5	6	7	NA
14. I learned to use the application quickly. <input type="checkbox"/>	strongly disagree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	strongly agree <input type="radio"/>
15. I easily remember how to use this application. <input type="checkbox"/>	strongly disagree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	strongly agree <input type="radio"/>
16. I quickly became skillful with the application. <input type="checkbox"/>	strongly disagree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	strongly agree <input type="radio"/>

SATISFACTION		1	2	3	4	5	6	7	NA
17. I am satisfied with the application. <input type="checkbox"/>	strongly disagree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	strongly agree <input type="radio"/>
18. I would recommend about the application to a friend. <input type="checkbox"/>	strongly disagree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	strongly agree <input type="radio"/>
19. This application is fun to use. <input type="checkbox"/>	strongly disagree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	strongly agree <input type="radio"/>
20. I feel I need to have this application. <input type="checkbox"/>	strongly disagree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	strongly agree <input type="radio"/>
21. This application is pleasant to use. <input type="checkbox"/>	strongly disagree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	strongly agree <input type="radio"/>

SYSTEM CAPABILITIES		1	2	3	4	5	6	7	NA
22. Is the application designed for all levels of users? <input type="checkbox"/>	strongly disagree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	strongly agree <input type="radio"/>
23. Application tends to be noisy? <input type="checkbox"/>	strongly disagree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	strongly agree <input type="radio"/>
24. Is the application reliable? <input type="checkbox"/>	strongly disagree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	strongly agree <input type="radio"/>
25. Is the speed of application, fast enough? <input type="checkbox"/>	strongly disagree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	strongly agree <input type="radio"/>

FIGURE 7. Questionnaire Used for the Teen Trust Application Survey.

its semantics. Group interactions based on trust will highlight more interesting insights such as group memberships,

Statistics

State Space

Nodes: 3413

Arcs: 11797

Secs: 10

Status: Partial

Scc Graph

Nodes: 3413

Arcs: 11797

Secs: 1

Boundedness Properties

Best Integer Bounds

	Upper	Lower
New_Page'Control_place	1	0
New_Page'Counter	1	1
New_Page'ability5	1	4
New_Page'accept_or_reject5	1	0
New_Page'address3	1	3
New_Page'all	1	3
New_Page'apps7	1	3
New_Page'basic	1	4
New_Page'benovelance6	1	4
New_Page'books6	1	3
New_Page'collefe2	1	3
New_Page'compatible4	1	4
New_Page'confidence3	1	4
New_Page'current	1	3
New_Page'dob	1	3
New_Page'email6	1	3
New_Page'events2	1	3
New_Page'familiarity2	1	4
New_Page'family	1	4
New_Page'games1	1	3
New_Page'high	1	3
New_Page'home	1	3
New_Page'integrity7	1	4
New_Page'movies4	1	3
New_Page'music3	1	3
New_Page'otherplaceslive3	3	0
New_Page'past_experience9	5	0
New_Page'ph	1	3
New_Page'places_you_lived1	4	0
New_Page'recently	1	3
New_Page'reject7	1	5
New_Page'relationship1	3	0
New_Page'reputation1	1	4

FIGURE 8. The Reachability Graph and State-Space Report for the Simulation.

trustworthiness, verification, subscriptions, inter-group, and intra-group interactions, etc. This group interaction based

```

New_Page'risk 1 1 0
New_Page'skills3 1 3 0
New_Page'sports5 1 3 0
New_Page'trust 1 1 1
New_Page'trustworthy8 1 4 0
New_Page'tv 1 3 0
New_Page'university5 1 3 0
New_Page'user_characteristics3 1
5 0
New_Page'work 1 4 0
New_Page'workplace1 1 3 0

Best Upper Multi-set Bounds
New_Page'Control_place 1
1`()
New_Page'Counter 1 1`0++
1`1++
1`2++
1`3++
1`4++
1`5++
1`6
New_Page'ability5 1 4`"if accept?"
New_Page'accept_or_reject5 1
1`false++
1`true
New_Page'address3 1 3`"if accept?"
New_Page'all 1 3`"if accept?"
New_Page'apps7 1 3`"if accept?"
New_Page'basic 1 4`"if accept?"
New_Page'benovelance6 1
4`"if accept?"
New_Page'books6 1 3`"if accept?"
New_Page'collefe2 1 3`"if accept?"
New_Page'compatible4 1
4`"if accept?"
New_Page'confidence3 1
4`"if accept?"
New_Page'current 1 3`"if accept?"
New_Page'dob 1 3`"if accept?"
New_Page'email6 1 3`"if accept?"
New_Page'events2 1 3`"if accept?"
New_Page'familiarity2 1
4`"if accept?"
New_Page'family 1 4`"if accept?"
New_Page'games1 1 3`"if accept?"
New_Page'high 1 3`"if accept?"
New_Page'home 1 3`"if accept?"
New_Page'integrity7 1
4`"if accept?"
New_Page'movies4 1 3`"if accept?"
New_Page'music3 1 3`"if accept?"
New_Page'otherplaceslive3 1
3`"if accept?"
New_Page'past_experience9 1
5`"if accept?"
New_Page'ph 1 3`"if accept?"

```

FIGURE 8. (Continued.) The Reachability Graph and State-Space Report for the Simulation.

on trust will promote open online interactions with prosperity. Also, prevention and discouragement of online bullying

```

New_Page'places_you_lived1 1
4`"if accept?"
New_Page'recently 1 3`"if accept?"
New_Page'reject7 1 5`false
New_Page'relationship1 1
3`"if accept?"
New_Page'reputation1 1
4`"if accept?"
New_Page'risk 1 1`false++
1`true
New_Page'skills3 1 3`"if accept?"
New_Page'sports5 1 3`"if accept?"
New_Page'trust 1 1`"checks in"
New_Page'trustworthy8 1
4`"if accept?"
New_Page'tv 1 3`"if accept?"
New_Page'university5 1
3`"if accept?"
New_Page'user_characteristics3 1
5`"if accept?"
New_Page'work 1 4`"if accept?"
New_Page'workplace1 1
3`"if accept?"
Best Lower Multi-set Bounds
New_Page'Control_place 1
empty
New_Page'Counter 1 empty
New_Page'ability5 1 empty
New_Page'accept_or_reject5 1
empty
New_Page'address3 1 empty
New_Page'all 1 empty
New_Page'apps7 1 empty
New_Page'basic 1 empty
New_Page'benovelance6 1
empty
New_Page'books6 1 empty
New_Page'collefe2 1 empty
New_Page'compatible4 1
empty
New_Page'confidence3 1
empty
New_Page'current 1 empty
No infinite occurrence sequences
New_Page'dob 1 empty
New_Page'email6 1 empty
New_Page'events2 1 empty
New_Page'familiarity2 1
empty
New_Page'family 1 empty
New_Page'games1 1 empty
New_Page'high 1 empty
New_Page'home 1 empty
New_Page'integrity7 1
empty
New_Page'movies4 1 empty
New_Page'music3 1 empty

```

FIGURE 8. (Continued.) The Reachability Graph and State-Space Report for the Simulation.

is another interesting research dimension. The systems can assist teenagers to apply the principles and expertise that will

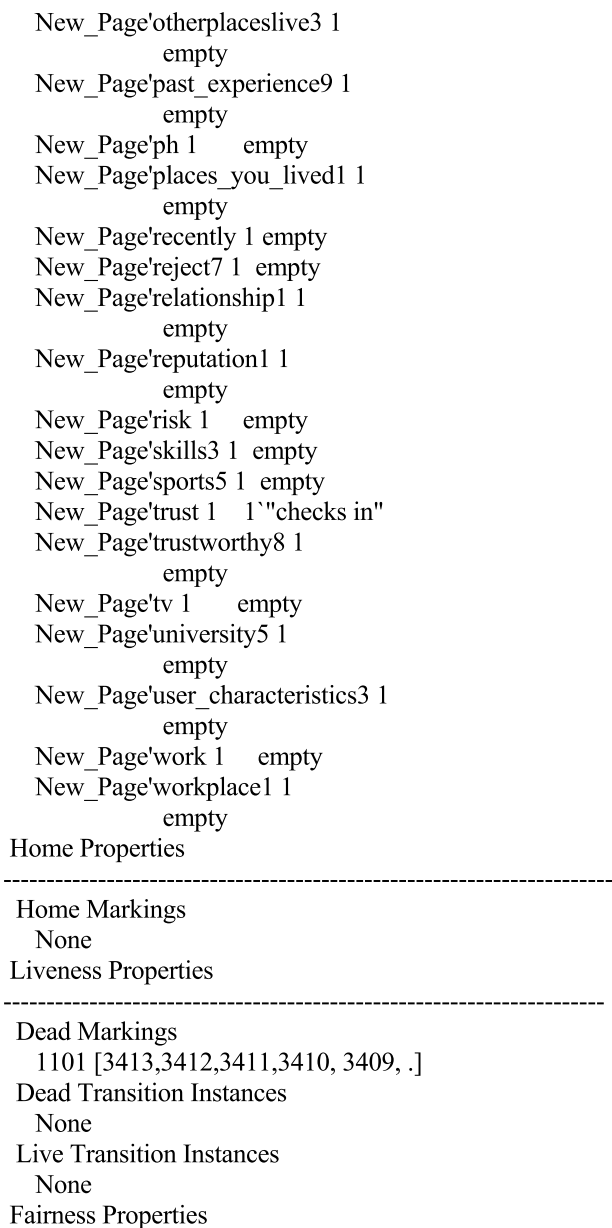


FIGURE 8. (Continued.) The Reachability Graph and State-Space Report for the Simulation.

help them develop positive relationships. A variety of friendship practices teach adolescents how to develop successful relationships, manage conflicts, and contribute to the lives of others. Every online social interaction offers teenagers a new opportunity to get to know different people and improve their social skills. Though, it is very crucial to keep in mind that teenagers can actually learn to choose and keep their friends through their personal experience, which inevitably leads to mistakes.

**APPENDIX I
QUESTIONNAIRE**

See Figure 7.

APPENDIX II

See Figure 8.

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