TCSN Newsletter –Issue Ten– December 2022

Social Networks Technical Committee

Editor: Prof. De-Nian Yang, Prof. Damla Turgut, and Prof. Burak Kantarci

TC website	https://sn.committees.comsoc.org/
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	Secretary: Prof. Burak Kantarci
Newsletter Editors	Prof. De-Nian Yang, Prof. Damla Turgut, and Prof. Burak Kantarci

For information about the newsletter, please contact dnyang@iis.sinica.edu.tw

CHAIR'S MESSAGE

When social media dominates the traffic over the Internet and mobile communication networks, there are further insights and engineering that could be developed based on understanding social networks in depth. Such interplay between technological networks and social networks has so many different aspects to inspire IEEE Communications Society members toward the further frontier of communication technology and benefits of human society. Under such background, Technical Committee on Social Networks (TCSN) is established in 2016, after incubation as a sub-committee in Emerging Technology. We believe that the TCSN newsletters allow us a more fluent exchange of vision, ideas, and technological opportunities, in addition to the website and social media platforms. We greatly appreciate all the members who have contributed to this issue of the newsletter. Last, but not least, we wish TCSN newsletters serve as an effective means for this exciting multi-disciplinary knowledge on social networks to blend humanity and technology in an even better way. Most important, please welcome you to actively participate or initiate more volunteer services to TCSN and IEEE Communications Society.

Best wishes,

Damla Turgut, Chair, TCSN, 2021-2022

UPCOMING CONFERENCES & CFP FOR SOCIAL NETWORKS TRACK

IEEE ICC 2023: May 28 – June 1, Rome, Italy
IEEE Globecom 2023: Kuala Lumpur, Malaysia

Social networks have become prevalent forms of communication and interaction on the Internet and contribute to an increase in network traffic. As a result, social networks have attracted significant research interests in many related areas. Social networks have traditionally been studied outside of the technological domains; however, the focus is now changing towards networking challenges such as cloud, privacy, data analytics, and so on while still keeping the social perspective such as focusing on improving quality of life. The interplay between social networks and technological networks such as mobile networks and mobile computing is becoming still strong and many areas are still to be exploited.

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USER-NETWORK INTERACTIONS FOR RESOURCE MANAGEMENT IN WIRELESS NETWORKS: A SOCIO-ECONOMIC APPROACH

Maria Diamanti, Symeon Papavassiliou
School of Electrical and Computer Engineering
National Technical University of Athens, Greece

Eirini Eleni Tsiropoulou,
Dept. of Electrical and Computer Engineering
University of New Mexico, NM, USA

The Multifaceted Nature of Interactions

The rise in popularity of smartphones, the need for personalized services with different Quality of Service (QoS) requirements and the emergence of 5G and social networks, has created and exponentially increased the interest in the broader area of mobile cyber-physical social systems. The economic and societal potential of such systems is vastly greater than what has been realized, and major investments are being made worldwide to develop the corresponding science and technology. Typically, these systems present competitive environments that induce constraints, while users evolve in a physical, digital, or virtual space with others, where their behaviors, interactions, and decisions become interdependent. Realizations of such systems include 5G wireless communication systems, Internet of Things (IoT) infrastructures, Multi-access Edge Computing (MEC), cyber-physical systems, and the intersection of these technologies with other disciplines, such as smart cities.

Existing approaches have unilaterally treated the problem of resource management and optimization in wireless networks. One stream of research assumes the existence of some omnipotent central entity that bears full knowledge about the underlying network's operation and, thus, steers the resource distribution procedure. In the direction of self-organizing networks, other approaches are devoted to the users' autonomous decision making regarding their personal resource utilization assuming their rationality. Nevertheless, the different stakeholders existing within the network - ranging from the end-user devices to mobile network operators and computing service and infrastructure providers just to name a few - are not only interconnected from technological viewpoints, but their interplay is additionally characterized by both social and economic dimensions. Apparently, this type of information cannot be explicitly communicated and shared in the network, while it usually regards conflicting objectives of the different stakeholders. Therefore, the key point that is missing from prior resource management studies is to concurrently model the user-network interactions and conclude to mutually beneficial points for them.

Asymmetry of Information

Future wireless networks technologically comprise multiple degrees of freedom in terms of architectures, employed technologies, provided services, and QoS requirements, presenting highly volatile and dynamic environments. The latter factors impose practical restrictions in the level of knowledge that a networked entity can have about the decisions and actions of the rest of the competing entities. Furthermore, from a social and economic perspective, the different entities' behaviors may be driven by competitive feelings and risks that primarily arise from the shared nature of the network resources, further promoting the asymmetry of information between them. With the advent of 5G and social networks, where billions of end-user devices are connected to wireless networks and new business entities emerge to make profit, this phenomenon and trend is intensified.

Contract Theory

The research path that is envisioned to effectively capture the user-network interactions under the scenario of asymmetric information is based on Contract Theory. Contract Theory was firstly introduced around 1960s, while its significance has been very recently recognized, when Jean Tirole was awarded a Nobel prize in Economic Sciences 2014 "for his analysis of market power and regulation". Two years later, a Nobel prize in Economic Sciences 2016 was awarded to Oliver Hart and Bengt Holmström "for their contributions to Contract Theory", further highlighting its potential in different application scenarios. In general, Contract Theory has been widely applied in different disciplines, such as industrial economics, public economics, banking, agriculture, and telecommunications.

Contract Theory studies the interactions between an employer(s) and an employee(s), by reconciling their conflicting goals and introducing in some way cooperation between them. The probability that the employees provide an ultimate good performance tends to increase as they work harder. However, if their offered compensation by the employer is independent of their performance outcome, they will be less likely to put effort in their work. At the same time, there exists some private information from the employees' behalf that is unknown to the employer and makes hard the decision upon the adequate level of compensation that motivates good work. Apparently, the design of appropriate incentive mechanisms, which take at the same time into account such an asymmetry of information between the two parties, plays an important role in order to conclude to mutually beneficial points.

Under a contractual agreement, the solution that is obtained is a menu of contracts intended for the employees, which targets at the maximization of the employer's utility/payoff. In most cases, the problem is formulated as maximizing an objective function that represents the employer's payoff, subject to the incentive compatibility constraint that each employee's expected payoff is maximized when participating in the contract, and the individual rationality constraint that each employee's payoff under this contract is larger than or equal to its reservation payoff when not participating at all. The problem is solved by the employer, by utilizing data and knowledge from the past regarding the employees' private information.

Contract Theory Enabling Resource Management

The employer and employees can map to different entities within the network setting, while their utilities can capture different metrics. For instance, a macro base station, Mobile Network Operator (MNO), or a Service Provider (SP) can play the role of the employer that is in charge of designing the menu of contracts intended for the employees, e.g., end-user devices or other base stations, operators, or providers. Apparently, a wide variety of optimization problems can be formulated, concurrently targeting different metrics form the network's and the users' perspective, e.g., energy and spectral efficiency, interference sensed and caused, fairness, and monetary profit.

Spectrum sharing in Cognitive Radio Networks: Cognitive Radio Networks (CRNs) are founded upon the idea of dynamically sharing the available bandwidth to increase its utilization level. In CRNs, the Primary Users (PUs) are allocated dedicated spectrum resources that can be leased by Secondary Users (SUs) for opportunistic use when they are vacant. This allows for the SUs to dynamically access spectrum resources, while the PUs make some monetary profit out of it. Nevertheless, the cost of leasing should be designed in such way that it is affordable and even beneficial for the SUs to participate in the CRN, based on their personal revenue gained when accessing the resources. The PU's problem of balancing the tradeoff between leasing cost and amount of resources to be leased, especially under the existence of asymmetric information regarding the SUs' wireless channel conditions and transmission power availability, can be directly mapped to the typical employer-employee contract agreement and solved via Contract Theory.

Delay-tolerant Computation Offloading: Consider a multi-tier mobile computing topology, consisting of an edge and a cloud computing service layer. The users tend to present a selfish and greedy behavior, overexploiting the resources of the edge service layer due to its proximity to them, which in turn yields lower transmission energy consumption and response times. The edge service provider can design an appropriate menu of contracts, comprising indicative percentages of the users' computation tasks to be further forwarded and processed at the cloud in exchange for some reduced subscription cost in the service. The contracts are designed based on the statistical knowledge of the provider regarding the user applications' level of intensity and QoS requirements. In this way, a more efficient point can be achieved for both the users and the edge service layer from monetary and operational perspectives, respectively.

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Maria Diamanti, mdiamanti@netmode.ntua.gr
Symeon Papavassiliou, papavass@mail.ntua.gr
Eirini Eleni Tsiropoulou, eirini@unm.edu

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LEVERAGING SOCIAL NETWORKS IN THE METAVERSE TO IMPROVE USER EXPERIENCE IN VR APPLICATIONS

BAY-YUAN HSU,

ASSISTANT PROFESSOR, DEPARTMENT OF INDUSTRIAL ENGINEERING AND ENGINEERING MANAGEMENT NATIONAL TSING HUA UNIVERSITY, HSINCHU, TAIWAN

CHIH-YA SHEN,

ASSOCIATE PROFESSOR, DEPARTMENT OF COMPUTER SCIENCE

NATIONAL TSING HUA UNIVERSITY, HSINCHU, TAIWAN

Virtual Reality (VR) has become popular and valued as a novel and state-of-the-art technology in recent years. With the advent and popularization of 5G, VR's practicability and development are becoming more mature. Many industries such as real estate, entertainment, e-commerce, and meeting platform are beginning to utilize VR to bring users a more innovative user experience. In addition, the advancement of sensing technology and hardware equipment allows people to do many new actions in virtual reality as same as humans can do in the real world and get rich feedback. Moreover, the trend of VR brings a new concept directly into the public eye: the metaverse. Metaverse is an interconnected and persistent 3D immersive virtual world, users can socialize, work, and play in this place but not be affected by the geographical location of the real world. Users can imagine that they are actually existing in this virtual world and feel like other people are there with them. In Japan, one of the most influential department stores Isetan Shinjuku[1] has developed a virtual shopping platform, which called REV WORLDS. They reproduce their real-world department stores in the virtual world, customers can control their 3D virtual avatars and walk in there. Besides, it provides a lot of functions that the real world has. Customers can ask virtual counters for product information, participate in limited-time activities, and enjoy shopping with friends. Meta Horizon Workrooms[2] develops Workroom this virtual space to let group members collaborate as if there are truly there. It is equipped with features like keyboard tracking, mixed-reality desk, hand tracking, and spatial audio. This helps teams work more efficiently even though they are remote.

Spatial[3], a 3D technology company, is dedicated to building customized virtual spaces such as exhibitions, brand experiences, and VR-based art-centric metaverse. One of its famous products is VR Art Gallery, which allows users and their friends to display 3D/2D artworks and visit virtual art

[1] https://www.rev-worlds.com/place/4

[2] https://www.meta.com/tw/en/work/workrooms/

[3] https://www.spatial.io/

galleries together. These applications help people collaborate and socialize "face-to-face", especially for those services that were originally provided on the Internet. Gartner[4], one of the world's most authoritative IT research and consulting companies predicts 25% of people will spend at least one hour per day in the Metaverse by 2026. Statista[5], a famous German company specializing in market and consumer data, did a survey about how much money users would spend on advanced VR gear, the results show that 65% of respondents were willing to spend up to 1,000 U.S. These statistical data represent a paradigm shift in people's social behavior. In addition, according to Influencer Market Hub data, the market value of the Metaverse will raise to $678.8 billion by 2030, which is about 17 times of the $38.85 billion in 2021. As mentioned above, the metaverse can seem like a real world in 3D space, which means there are social networks inside them. Metaversed[6], the original metaverse consulting company points out that the monthly active users in the metaverse are over 400 million, which is a new record. Besides, there is another survey provided by Statista that indicates 74% of adults in the United States are considering joining or already joining the metaverse. That is to say, the social networks in the metaverse are growing explosively in recent years. And social networks this topology, which hides the social relationship between members, has a huge influence that should not be underestimated.

Related works about social networks in VR

The metaverse world that is extended by VR is very different from the real world because its interactivity and functionality can not only simulate the scenes and interactions of the real world but also beyond the real world. Besides, with the advancement of hardware and sensing technology, the feedback has become richer and the convenience of manipulation has greatly improved. In this regard, the impact of VR is a completely new architecture, which is worth studying. Some studies are exploring how to use social networks to improve or augment users' experience in VR applications, thereby achieving user recommendations in VR. The sociability experienced by users in the metaverse is also a subject of research, two factors have been researched in previous works: view obstruction and digital twin. View obstruction means when a user is in a crowded 3D virtual space, it may not be an easy task to find the user he is interested in like what they can do in the real world. Digital twin means the characters in the VR world can be controlled by real people or AI. When the user is in the metaverse, he may want to interact with digital twins that are controlled by different methods due to the current situation. In addition to recommending people, the recommendation of items and the extraction of subgroups in social networks is also a research direction that can be combined with real-world applications.

Moreover, just like we have all kinds of social networks in real life, there are many different types of social networks in the metaverse. Using VR functions to build social networks rather than using social networks that get from traditional social media is also worth developing. Simulation and getting feedback are very important features in VR. Especially for those things which are not able to operate

[4] https://www.gartner.com/en/newsroom/press-releases/2022-02-07-gartner-predicts-25-percent-of-people-will-spend-at-least-one-hour-per-day-in-the-metaverse-by-2026

[5] https://www.statista.com/statistics/1288805/money-spent-advanced-vr/

[6] https://www.linkedin.com/pulse/metaverse-reaches-400m-monthly-active-users-metaversed?trk=pulse-article_more-articles_related-content-c

in the real world because of their limitations or inappropriateness. So how to use VR for repeatedly simulation and training to improve skills in the real world is another important direction that many people are doing related research. Besides, in order to realize sociality in VR, technical support is also required and critical. The transmission and calculation of large amounts of data also mean that there will generate transmission delays. If there are continuous delays in the social interaction process, it will have a huge impact on user experience.

It can be seen that for VR, the aspects that can be researched are quite diverse. The following are further descriptions of the above-mentioned aspects.

1. User recommendation: Take VR conference applications as an example, the problem that may occur is that users may be surrounded by attendees that they are not interested in or unfamiliar to them. It will be a good way to improve users' experience by using social networks to customize the display of attendees. Specifically, we can arrange the attendees in different ways like preference-based configuration or social-based configuration. Preference-based configuration means the attendees displaying to users are the people that they are highly interested in. Social-based configuration means users see the people they are closed or homogenous.
2. Socializing in the metaverse: For view obstruction, because different VR products have different functions and movement limitations. The degree of freedom will not be the same as in the real world unless the VR hardware equipment can be developed to be completely realistic. And digital twins, if we are in a virtual store, the digital twins are controlled by AI can provide users with more complete product information. However, if users are exploring the metaverse, they may prefer the digital twins which are controlled by real people or by your friends. To be able to have good social interaction in the metaverse, it needs to consider the things and scenes presented in the window, and most importantly, interact with real people or AI.
3. Optimizing items and subgroups: For shopping in VR, the core concept is the right thing that corresponds to the right person. There is a feasible method that divides a period of time into multiple time slots, and in these time slots, different subgroups can be constructed according to their social network and personal preferences. Then the store can display different products for these subgroups. In other words, it satisfies the customization needs of personal preferences and also allows group members to have the opportunity to interact with each other.
4. Using VR to extract subgroups or build social networks: If there is a following function like the current social media, a social network based on user following can be built. But in the metaverse, its interactivity is different from traditional social media, there are more diverse ways to build social networks or extract groups in social networks. There are studies that aim to use VR games to organize or establish a closer social group, thereby enhancing the user experience. Therefore, VR can also be a novel way to extract diverse subgroups and build a new type of social network.
5. VR for training: Another feature of VR is that it allows users to simulate many things that might not be possible to do in reality because of limitations or inappropriateness and get vivid feedback. For example, there is research exploring how VR can be used to improve social cognition for children with high-functioning autism. Compared to reality, VR is a controlled environment, so safe and unrestricted situations can be designed to help these children practice everyday social situations, such as interacting in the classroom. By using VR applications, the training can be repeated without limitation on the number of times, and with the help of AI, the use of human resources can also be reduced.

6. Edge computing for VR: Edge computing is the research direction for such problems. For collaboration in VR, extremely low latency is required to meet the accuracy of multi-person real-time interaction. For games, low latency can ensure the fairness of players. How to appropriately deploy resources on edge infrastructure, do data computation, and scene rendering are the research purposes in these works.

Authenticity and Social Behavior in Metaverse

In addition to effectively exploiting various properties in the metaverse to develop VR applications or using social networks to improve VR applications, the birth of the metaverse is accompanied by many questions about human behavior and psychology. One feature of the internet is that we can control our authenticity. Specifically, users can decide how much personal information they want to disclose based on the social media they use, especially in the metaverse. The digital twins in the metaverse can be seen as an avatar of users in this world, and the customizability of their appearance and the personal information they disclose can easily influence and manipulate others' first impressions of them.

Furthermore, whether people's social behavior in the metaverse will change and the motivation to use VR is also an issue that many works are exploring. What kind of situations are more suitable for using VR or what kind of interactions are provided in VR can affect sociality? Business, education, law, and ethic are the issues related to it.

Except for the above-mentioned issues, there are still many directions to be studied. With the increasing demand for remote collaboration and work, the prospect of VR is promising. Sociality in VR will be one of the important parts of VR research.

Bay-Yuan Hsu,
byhsu@ie.nthu.edu.tw
Chih-Ya Shen,
chihya@cs.nthu.edu.tw

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INTELLIGENT CONNECTION MANAGEMENT FOR SOCIALLY NETWORKED VEHICLES

CHIH-WEI HUANG,

ASSOCIATE PROFESSOR, DEPARTMENT OF COMMUNICATION ENGINEERING

NATIONAL CENTRAL UNIVERSITY, TAOYUAN, TAIWAN

IBRAHIM ALTHAMARY,

RESEARCH FELLOW, DEPARTMENT OF COMMUNICATION ENGINEERING

NATIONAL CENTRAL UNIVERSITY, TAOYUAN, TAIWAN

WEN-HSING KUO,

PROFESSOR, DEPARTMENT OF ELECTRICAL ENGINEERING

YUAN ZE UNIVERSITY, TAIWAN

SHIH-HAU FANG,

PROFESSOR, DEPARTMENT OF ELECTRICAL ENGINEERING

YUAN ZE UNIVERSITY, TAIWAN

Vehicle-to-everything (V2X) network is an emerging communication type for intelligent transportation systems (ITS). It has to support different data traffic with high data rates, low latency, and extreme reliability. More importantly, it must allow mission-critical applications to operate precisely to avoid accidents and protect human lives. Therefore, radio connections have to be effectively managed with socially cooperative vehicles to achieve the above goals and maximize network performance. Given the complexity of the vehicular social network environment and the time-varying data traffic requirements, building such a system is challenging and worth studying.

Vehicular Social Networks

As the number of vehicles grows, cellular V2X (C-V2X) technology is the future trend to mitigate traffic congestion and accident occurrence. It enhances autonomous driving and improves information exchange for diverse vehicle-sharing systems such as passenger cars, emergency vehicles, and transport services. There are several communication types in V2X networks; each aims for different applications and corresponding requirements. Vehicle-to-infrastructure (V2I) mainly serves throughput-demanding data streams to the backbone networks and thus requires high bandwidth.

On the other hand, vehicle-to-vehicle (V2V) is mainly designed for mission-critical and short-distance applications among cars. Also, vehicle-to-satellite (V2S) communication seeks to satisfy the above applications in rural or congested areas lacking sustainable V2I and V2V connectivities.

Recently, the concept of "vehicular social networks" has become an active research topic in V2X networks. Vehicular social networks assume each vehicle has corresponding identities, applications, and connection needs, thus requiring interdependent information and transmission patterns. Instead of operating individually or broadcasting ubiquitously in such a network, vehicles share information with others and make more promising decisions. Besides the connections mentioned earlier, such as V2V, V2I, and V2S, vehicular social networks also involve vehicle-to-pedestrian (V2P) communications, where passengers and motorists can obtain information and socialize on roads. Vehicular social networks represent the future communication platform that integrates V2X and social networks.

On the other hand, as cellular network technologies evolve from 5G to 6G, NR (New Radio) V2X is designed for vehicular communications. NR V2X is the recent wireless radio technology developed by the 3rd Generation Partnership Project (3GPP) starting from Release 15, providing sideline communication modes for V2X scenarios. Mode 1 allows base stations to manage resources for UE transmission; Mode 2, which utilizes pre-allocated resources, is more suitable for point-to-point social V2X services and can ensure lower latency and more flexibility. Furthermore, this communication mode allows autonomous vehicles to determine appropriate transmission resources and provide assistance information to other vehicles. Therefore, it is considered an attractive research direction feasible for constructing vehicular social networks.

Intelligent Connection Management for V2X

Building vehicular social networks, including V2I, V2V, V2S, and V2P connections, and providing satisfactory transmission coverage is challenging, especially in rural areas with low infrastructure density or complex urban areas with overwhelming traffics. Seamlessly integrating or switching between accessible connections to fully take advantage of the infrastructure becomes a problem to tackle.

Machine learning (ML) approaches have been explored for solving this distributed issue. Compared with conventional heuristic solutions, ML may achieve favorable cost-benefit tradeoffs in the complicated V2X environment. Treating the vehicle as a smart agent, deep reinforcement learning (DRL) and its variations have advanced the adoption of trained intelligence to solve resource management problems in V2X. However, straightforward single-agent reinforcement learning (SARL) has difficulty handling large-scale and diverse situations due to its centralized nature and homogeneous agent behavior. Moreover, to collaborate and socialize among smart agents, the signaling overhead can also be significant and thus prevent the algorithms from running in the real world.

Evolving from SARL, multi-agent reinforcement learning (MARL) shows the potential to cope with connection management problems in vehicular social networks. By allowing agents to make actions and evaluate rewards differently, a MARL system enables effective decentralized decisions and can be more scalable. As a result, the demand for managing connections in diverse large-scale vehicular social networks could be fulfilled. Also, the agents are often assumed to make decisions without global information and modeled as a partially observable Markov decision process (POMDP) to depict the environment practically. The problem often targets maximizing system utility while meeting strict requirements, e.g., ultra-reliable and low-latency communications (URLLC). Thus, augmented by information sharing and estimation across smart agents, the agents can overcome the limits of their environmental vision and make more beneficial and cooperative decisions.

Future Research Directions

Adopting MARL or other machine learning approaches to vehicular social networks is a promising research field. The major challenges to be addressed include:

1. Developing scalable learning frameworks for heterogeneous vehicular network topologies. That involves what to centralize and decentralize in a multi-agent system with diverse individual requirements. How to socially cluster vehicles for more effective model learning can also be essential.
2. Learning models under non-stationary conditions. MARL agents may improve according to their own interests, resulting in non-stationary environmental dynamics. How to embed socialized cooperation in the model has to be considered.
3. Reducing communication overheads. Information sharing can mitigate the effect of partial observability, but the amount of data collected during the process can be significant. Efficiently extracting information from vehicular social networks remains an issue to be tackled. A reward-based framework can be applied to encourage efficient sharing, while deep learning-based prediction models can provide a decent estimation of the global state.
4. Accurate channel estimation and congestion detection. Due to the dynamics of wireless channels, estimation of channel quality is not trivial, especially in situations involving multiple connections. The proposed resource allocation scheme should be able to correctly evaluate the channel qualities and consider the mobility of vehicles accordingly.
5. Advancing MARL theories with social models in mind. Model-based MARL algorithms are less investigated in the literature, while abundant studies of social models can be applied to vehicles to improve their performance under MARL training efficiency.

Chih-Wei Huang, cwhuang@ce.ncu.edu.tw
Ibrahim Althamary, 106583603@cc.ncu.edu.tw
Wen-Hsing Kuo, whkuo@saturn.yzu.edu.tw
Shih-Hau Fang, shfang@saturn.yzu.edu.t