TCSN Newsletter – Issue Fourteen – December 2024
Social Networks Technical Committee
Editors: Prof. Chih-Wei Huang and Dr. Claudio Marche

TC website	https://sn.committees.comsoc.org/
TC officers	Chair: Prof. De-Nian Yang
	Vice-Chair: Prof. Burak Kantarci
	Secretary: Prof. Abderrahim Benslimane
Newsletter Editors	Prof. Chih-Wei Huang and Dr. Claudio Marche

For information about the newsletter, please contact claudio.marche@unica.it

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, 2024-2025

UPCOMING CONFERENCES & CFP FOR SOCIAL NETWORKS TRACK

IEEE ICC 2025: 8-14 June, Montreal, Canada
IEEE Globecom 2025: 8-12 December, Taipei, Taiwan

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.

TCSN Newsletter – Issue Fourteen – December 2024
Social Networks Technical Committee
Editors: Prof. Chih-Wei Huang and Dr. Claudio Marche

WHEN QUANTUM NETWORK MEETS SOCIAL NETWORK – SOCIALLY-AWARE QUANTUM KEY DISTRIBUTION MECHANISM

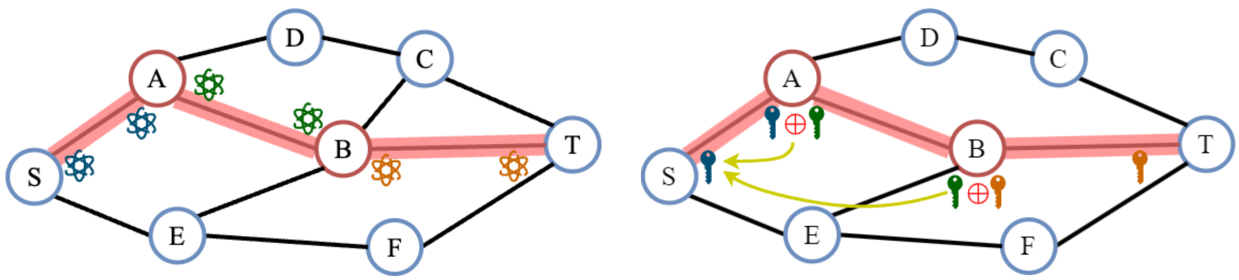
Jian-Jhih Kuo
Dept. of Computer Science and Information Engineering
National Chung Cheng University, Taiwan

Wan-Ting Ho
Dept. of Computer Science
National Tsing Hua University, Taiwan

Chun-An Yang
Dept. of Computer Science
National Tsing Hua University, Taiwan

Quantum network technology is expected to change communication networks by introducing unprecedented levels of security in key distribution and transmission. By enabling quantum communications, QKD sets a new standard for digital security and privacy on interconnected platforms. QKD, a cryptographic protocol based on quantum mechanics, securely facilitates *secret key exchange* between the communicating parties. Specifically, a *quantum photon source (PS)*, which is deployed at least one of the two parties, generates photons encoded with quantum information. Photons are transmitted through optical fibers and measured by both parties to establish a secret key. Since any observation or measurement during key generation can alter the quantum key states, eavesdropping becomes impossible, effectively addressing traditional network concerns, such as attackers intercepting or stealing keys.

However, the *quantum key rate* decreases significantly as the transmission distance increases. The key rate refers to the ratio of the number of bits in the final generated key to the time taken to produce it (i.e., the efficiency of successfully generating a key) through a series of processes, including raw key measurement, bit error rate calculation, error reconciliation, and privacy amplification. A lower key rate will either prolong the time to generate a key (i.e., lower transmission efficiency) or increase security risk (i.e., fewer bits in a key). For long-distance communications, a commonly used method involves *trusted relays* along a transmission path. A typical QKD transmission process is as follows. First, a trusted relay path is established between each source and destination pair. Second, a quantum key is generated between each adjacent node pair along this path and converted into a classical key at each intermediate node. Each intermediate node performs an XOR operation on its two classical keys and transmits the result to the source. By aggregating these XOR results, the source recovers the classical key of the destination, which will be used to encrypt messages for secure delivery. Note that relays must be trusted to ensure the correct XOR results and secure generated keys. This mechanism maintains high-level communication confidentiality and ensures secure data transfer over extended distances in QKD networks.



(b) Adjacent nodes share quantum keys **(a) Relay nodes XOR their quantum keys**

Figure 1 - An illustrative example of QKD transmission, where nodes S (source), T (destination), and A~F are quantum nodes.

For ease of understanding, Figure 1 illustrates the QKD transmission workflow. Each node represents a quantum node, and each link signifies a quantum channel (e.g., optical fiber) connecting two adjacent quantum nodes within a QKD network. In this example, the source S determines and establishes a trusted relay path to the destination T (i.e., $S \rightarrow A \rightarrow B \rightarrow T$), as indicated by the red lines. First, any two trusted relays on the path (including the source and destination) (S, A), (A, B), and (B, T) share a quantum secret key, respectively, as shown by a blue, green, and orange atom icon in Figure 1(a). Next, in Figure 1(b), each intermediate node (i.e., A and B) measures two quantum keys it possesses, converts them into classical bits (represented by key icons), performs an XOR operation on its two keys (i.e., blue and green keys for A, green and orange keys for B), and shares the result with the source S. Finally, S computes the classical key of the destination T (i.e., orange key) using the XOR results, and the data encrypted with this key is then transmitted from S to T, ensuring secure transmission.

Integrating social networks with QKD mechanism can significantly enhance the security and flexibility of service requests by considering the varying *trust levels* between nodes. In social networks, a specific level of trust is established between each pair of nodes. When a request needs to be securely transmitted from a source to a destination, a trusted relay path will be established based on the trust levels between nodes. Specifically, the nodes selected as trusted relays in a trusted relay path must meet the minimum trust thresholds set by both the source and the destination. Therefore, more critical requests must be transmitted through trusted relays with higher trust levels, while less critical requests can leverage a larger pool of available trusted relays. By combining QKD mechanism and social principles, the system achieves reinforced security by quantum key encryption technology and flexible trusted relay path selection with different trust levels.

Although the integration of QKD mechanism with social networking can bring lot of benefits, there are still significant challenges to achieve this ideal transmission: *1) High PS deployment cost and limited quantum channel capacity*. Deploying a PS can be extremely costly, with expenses potentially reaching hundreds of thousands of dollars. This financial barrier, combined with the limited capacity of quantum channels, makes it challenging to achieve large-scale deployment of PS in QKD networks. *2) Limited number of quantum keys*. The quantum key rate is inversely proportional with transmission distance. In order to ensure security, some protocols regulate a certain number of bits needed in a key, e.g., 128 or

256 bits. A lower key rate will lead to a lower number of keys, further reducing request satisfaction. Therefore, it is important to determine the proper trusted relays in a longer transmission path to enhance the number of available keys. *3) Trusted relay path selection*. In addition to the difficulty of quantum key generation, establishing a trusted relay path requires relays that are trusted by both the source and destination to a certain degree. This limitation enhances security but complicates efficient transmission and the simultaneous satisfaction of requests from multiple source-destination pairs. *4) Trust level assessment*. The nodes that have to perform XOR on the trust relay path must be trusted by the source and the destination. Thus, assessing the trust level between nodes are an important issue. Moreover, it will be interesting to consider all-optical switching technology to bypass potential malicious nodes (i.e., nodes with a low trust level for the source and the destination). Trusted relay QKD transmission involves several non-trivial trade-offs. Consequently, designing an effective PS deployment, trusted relay path selection strategy, and trust level assessment scheme to efficiently serve network requests has become critical in socially-aware QKD networks.

Overall, a socially-aware QKD network offers distinct opportunities to enhance security and efficiency, providing significant advantages over traditional communication networks. These advantages stem from the unique transmission features of QKD and the trust relationships between nodes facilitated by social networks. Together, they establish a new paradigm for secure and efficient data transmission across interconnected networks.

Jian-Jhih Kuo,
lajacky@cs.ccu.edu.tw

Wan-Ting Ho,
s111062573@m111.nthu.edu.tw

Chun-An Yang,
s110065505@m110.nthu.edu.tw

TCSN Newsletter – Issue Fourteen – December 2024
Social Networks Technical Committee
Editors: Prof. Chih-Wei Huang and Dr. Claudio Marche

CONNECTING DISTANT DOTS: FEED-FORWARD LOOPS AS COMMUNITY SPANNERS

ARINDAM KHANDA
POSTDOCTORAL RESEARCHER, DEPARTMENT OF COMPUTER SCIENCE
MISSOURI UNIVERSITY OF SCIENCE AND TECHNOLOGY, USA

SATYAKI ROY
ASSISTANT PROFESSOR, DEPARTMENT OF MATHEMATICAL SCIENCES
UNIVERSITY OF ALABAMA IN HUNTSVILLE, USA

PRITHWIRAJ ROY
DATA SCIENTIST AT GLOBAL ACTION ALLIANCE, USA

SAJAL K. DAS
PROFESSOR, DEPARTMENT OF COMPUTER SCIENCE,
MISSOURI UNIVERSITY OF SCIENCE AND TECHNOLOGY, USA

Social networks emerge as a vital evolutionary strategy, offering individuals and groups enhanced chances of survival and success through cooperation, resource sharing, and collective protection. The tendency to connect with others based on shared traits and interests, known as *homophily*, fosters trust and mutual understanding. Additionally, the intrinsic reciprocity in social ties ensures the exchange of resources, making relationships mutually beneficial from a survival standpoint. These networks act as social safety nets, distributing information and providing aid during crises, which have proven crucial for human survival throughout history. Concepts like structural balance and triadic closure strengthen these networks by creating tightly knit communities that reinforce trust and resilience. Today these evolutionary advantages have extended to virtual platforms, where social media leverages the same principles of connection and cooperation. Digital networks transcend geographic barriers, allowing individuals to form *communities* based on shared interests and goals rather than mere proximity.

Network motifs and structural hole spanners represent two critical entities in understanding the dynamics of social networks, each contributing uniquely to their structure and functionality. Motifs are recurrent patterns of interconnections that enhance network robustness, ensure stability, and optimize communication pathways. These small, repeating structures—such as *feed-forward loops* or triangles—offer localized resilience, ensuring that the failure of a single node or edge does not disrupt the overall connectivity. Motifs also streamline information dissemination by creating efficient, reliable channels within dense network regions, reinforcing their role as foundational units of social systems. On the other hand, structural hole spanners serve as bridges between otherwise disconnected communities within a network. These nodes or edges traverse the sparse spaces between distinct communities, facilitating the exchange of information, ideas, or resources across social groups. This bridging capability makes them essential for promoting innovation, as they enable diverse perspectives to intersect and collaborate. Our efforts aim to explore the intersection of these two phenomena—specifically, whether network motifs can also function as structural hole spanners and vice versa. By investigating such an overlap, the aim is to uncover insights into how robust localized structures might bridge gaps between communities, thus uniting the dual goals of stability and interconnectivity.

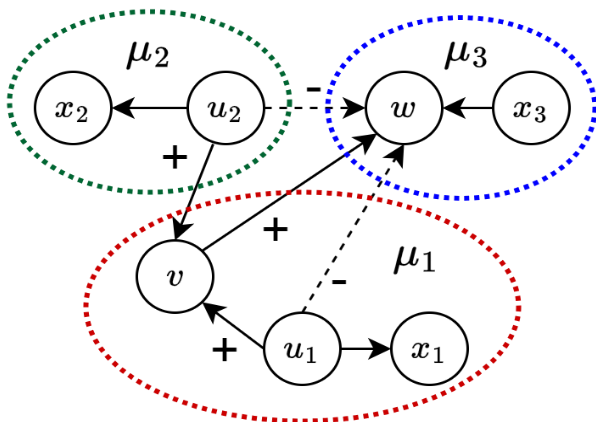


Figure 1 - Strong and weak ties are denoted using positive and negative edge weights respectively. Colored circles denote communities.

Specifically, we explore an approach to identify the top structural hole spanners (SHSs) in weighted, directed social networks by leveraging the concept of network motifs[1]. It focuses on feed-forward loops (FFLs), a common motif in social networks, to quantify a node's likelihood of acting as a structural hole spanner. In this framework, a FFL — directed triad composed of nodes *u1, v,* and *w* connected by links *(u1, v), (v, w),* and *(u1, w)* — are interpreted as a mix of strong and weak ties. The links *(u1, v)* and *(v, w)* are strong ties representing a primary channel for reliable, high-bandwidth information flow, while the weaker ties *(u1, w)* represent a less reliable channel with lower bandwidth (as illustrated in **Figure 1**). We quantify a node's role in spanning network communities through its participation in FFLs. This approach bridges the gap between the structural abundance of motifs in large social networks—known for their *small-world* properties—and the critical function of spanners in facilitating efficient, long-distance information flow across sparse, interconnected communities. The concept of a spanner vertex can be extended to a spanner motif, where an FFL can effectively span across different communities. The quality of an FFL motif spanner can be quantified as the cumulative contribution of all vertices within the motif to bridge various communities.

[1] A. Khanda, S. Roy, P. Roy, and S. K. Das, "Structural hole spanners detection in directed social networks: A feed forward loop motif approach," to appear in the proceedings of IEEE Global Communications Conference (GLOBECOM), IEEE, 2024

The rapid dissemination of information and the influence of collective norms mirror traditional social influence mechanisms but at an unprecedented scale. The small-world phenomenon, characterized by attributes that enable most nodes, which are not directly connected, yet can be reached through a short series of steps, plays a pivotal role in understanding the robustness of telecommunication networks. This property ensures reduced latency and improved routing, allowing for efficient communication between distant nodes. The internet and telecommunication systems leverage this inherent small-world structure to enhance resilience, enabling robust performance even under high-demand scenarios or localized failures. However, the interconnected nature of social networks, mirrored in these systems, introduces challenges such as congestion, traffic management, and the complexity of designing optimal routing protocols. Telecom companies must address these issues to maintain seamless communication, particularly as demand for high-speed, low-latency services grows.

The convergence of telecommunication and human social networks has become evident with technological advancements such as 5G, IoT, and fiber optics, which have transformed how people share information globally. The blend of communication tools with social networking functions creates spaces where digital and social interactions seamlessly overlap. This convergence has profound societal implications, influencing social dynamics, privacy, and digital identity management, reshaping how individuals and communities engage with content, brands, and services. This highlights the evolving intersection between technology and human behavior.

The recent advances in artificial intelligence, machine learning, and big data are driving new applications in both human social and telecommunication networks, such as personalized recommendations and predictive analytics for social trends, which are transforming how we interact online. This convergence of technology is also giving rise to innovative services like telemedicine, virtual communities, and smart cities, which rely on both robust social connectivity and advanced telecom infrastructure to function effectively. Looking ahead, emerging technologies like augmented reality (AR) and virtual reality (VR) are set to further revolutionize social interactions, with significant implications for both telecommunications and social networks, creating immersive, interactive environments that redefine communication and connectivity in the digital age.

Arindam Khanda,
akkcm@mst.edu

Satyaki Roy,
sr0215@uah.edu

Prithwiraj Roy,
przhr@mst.edu

Sajal K. Das,
sdas@mst.edu