My scholarship examines the design, modeling and evaluation of novel mechanisms for use in CPS/IoT environments, and leverages learning techniques to anlayze the data generated therein, in particular, users' cyber-physical behaviors as well as their social networks and socioeconomic status. My research includes investigating (1) how data communication and data analytics interactively shape the future ICT development; (2) how advances in machine learning enable new applications in the ICT sector as well as the human society; and (3) whether and to what extent such knowledge would be applicable for improving ICT system design, user experience and broader community.

Research Contributions

Over the years, I have been extremely fortunate to be exposed to multiple projects and ideas from different researchers and collaborators from both the academia and the industry. These experiences have been both enjoyable and enlightening, providing me with profound experiences and perspectives on related research fields.

Based on these experiences and my independent studies I have successfully initiated, supervised and actively contributed to various research programs, including EU FP6 ENABLE (IST), Vidios (Eureka), MING-T (IST), FP7 GreenICN (EU-Japan), MobileCloud (IRSES), CleanSky (ITN) as well as H2020 ICN2020 (EU-Japan) and COSAFE research projects, plus other national and international ones.

Each of the above-mentioned activities has either led to referred publications, open source implementations, patent applications, or other forms of contributions to the community (e.g., standardization). Among these publications, I received the 2005 University of Göttingen Foundation Council's Exceptional Publication Award for Young Scholars as well as several ACM/IEEE conference best paper awards. Through my academic career, I have authored over 300 peer-reviewed publications in journal and international conferences, including many top ranked and highly selective ones. I expect to generate a continuous stream of publications and other contributions with high impact in the future.

One of my core interests is to embrace the opportunities enabled by connected vast CPS/IoT devices, by extending the current design for IoT and developing new applications for machine learning: for example, scenarios where the edge computing and ICN concepts for enable massive IoT data delivery, scenarios where we have access to users' trajectories/location data and behavior, and wish to get better understanding of related knowledge such as user preferences and socioeconomic status. In particular, one common thread throughout much of my work is the use of social network analysis, spatiotemporal trajectory/behavior analysis and machine learning to gain improvements in performance compared to standard approaches. Some selected contributions are summarized as follows:

Advanced protocols and mechanisms for enhanced (IoT/Internet) data communications (ICNP'04, INFOCOM'06, ToN'09, ICNP'09, ANCS'11, CoNEXT'13, TVT'14, IoTJ'16, IoTJ'17, SIGCOMM'17, TPDS'17, CoNEXT'18, JSAC'18, JSAC'19, WWWJ'20, TPDS'20, TMC'20, ICDCS'21, ToN'21, EWSN'21, TIT'22): To effectively support efficient and resilient data delivery, we develop numerous mechanisms for ICN and Internet/IoT systems,

including routing, scheduling, congestion control, naming, and massive content dissemination.

Resilient and energy-efficient mobile edge computing, crowdsourcing and D2D communications (ToN'16, INFOCOM'16, JSAC'16, JSAC'17, TVT'18, TMC'19, IoTJ'19, IoTJ'20): To deal with the resource constraint challenge in IoT environments, we introduce different strategies: 1) optimal mobile edge computing where code/tasks can be offloaded to edge cloud; 2) enabling D2D communication by leveraging the capacity of nodes in proximity; 3) integrating user preference into the task crowdsourcing process.

Analyzing users' trajectories and behaviors (INFOCOM'14, WWW'14, TKDE'15, WWW'17, CAN'17, WWW'18; TKDD'18, ICCCN'19, JSC'21, IJCAI'21, TWEB'21, MSN'21): We analyze users' behaviors, identify their trajectories based on which to understand their behavior patterns, structure, dynamics and socioeconomic status.

Exploiting data analytics and learning techniques to identify bots and malicious users/nodes (CoNEXT'12, NetworkingScience'13, COMNET'14, TIFS'14, TSC'15, EWSDN'15, HotPOST'17, ComMag'18, BigDataMiningAnalysis'18, ComMag'19, TDSC'21): We apply machine learning techniques to detect anomaly users (or users with distinct cultures) and their traffic/data in Internet-based communications, including location-based social networks.

Exploring user/application requirements, preference and/or their interactions to improve the communication infrastructure (Middleware'11, ICNP'12, INFOCOM'14, Middleware'14, ToN'16, INFOCOM'16, FGCS'18, TNSM'19, TSC'19, TMC'19, ToN'21, IWQoS'21, TMC'21): To improve the resource utilization and energy efficiency, we attempt to incorporate more intellegence/knowledge of users, in particular their social relationships and preference.

Future Research Directions

Much of my research and teaching over the years has been geared towards tackling the emerging challenges and embrace the opportunities of cyber-physical systems and data analytics technologies, including but not limited to mining and fusing heterogeneous spatial-temporal data on individual, group and/or societal levels, in collaboration with intelligent and scalable ICT infrastructure designs. For instance, the items listed below lay out opportunities in future research agenda:

Infrastructure design and data-driven applications for cyber-physical systems: We note that novel sources of data, such as various IoT sensors like street/building surveillance cameras, vehicular or passenger records, smart phones, as well as social media, have enabled a number of applications and services, including but not limited to public space surveillance, vehicular traffic optimization, smart manufacturing and logistics. For the sake of efficient dynamic urban resource management and infrastructure planning, understanding the information interactions and dynamic processes of CPS is critical. As a result, it is useful to develop effective (mobile) edge computing infrastructure for supporting efficient and scalable

CPS data communication on one hand, and to exploit rich CPS data for enabling various applications (e.g., avoid/mitigate traffic congestion, help event detection and decision making/recommendations, improving both user experience and environmental conservation) on the other hand.

Artificial intelligence, machine Learning and applied data analytics: We apply – and extend where applicable – AI/ML techniques in (multidimensional) data analytics to understand the functionality, dynamics and applications of network structure and interaction patterns of various individuals and groups, including their socioeconomic status and emotional, mental and behavioral responses towards different situations in both temporal and spatial dimensions, and devise customized intervention schemes for related people (e.g., online shopping consumers, adolescents, citizens and communities involved in public safety and public health scenarios, etc.). Furthermore, today's Internet has been designed to be rather dumb and inflexible without much consideration of user experience and application knowledge. The unprecedented amounts of network traffic and the rise of complex, application-aware services not only pose new challenges, but also offer new opportunities with its virtually unlimited amounts of data and metadata enabling more intelligent ICT designs, empowered by the advanced AI/ML methods.

Security analysis and defense: Security and privacy continues to remain a top concern in the physical and cyber worlds, in particular, due to the vast data produced by various CPS/IoT devices and Internet users nowadays. The diversity, scale and number of malicious behaviors and cyber-attacks in the cyber-physical world pose a strong demand in anomaly node/user and attacker detection and defense mechanisms, which require to be effective against intelligent and adaptive adversaries. Hereby AI/ML will play an important role, for modeling user behaviors and interaction/activity patterns, extracting and integrating essential features from various data sources, and eventually predicting and designing effective defenses.

Concluding Remarks

The above topics give some of the overall flavor of my work. In the future, I plan to continue advancing the state of the art in cyber-physical systems and application-aware systems in the information technology era, applying and expanding my experience to the very research front.